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Heat Pump Program
Programme des pompes de chaleur

# *Application of a Heat Pump in the Pulp and Paper Industry*

G.A. Robb Associates

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# APPLICATION OF A HEAT PUMP IN THE PULP AND PAPER INDUSTRY

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## APPLICATION OF STEAM GENERATING R114 HEAT PUMPS FOR INTERMEDIATE QUALITY ENERGY RECOVERY IN THE CANADIAN PULP AND PAPER INDUSTRY

### EXECUTIVE SUMMARY


The development and demonstration of a steam generating R114 heat pump is proposed. The thermal output should be roughly 16 GJ and the steam pressure between 34kPa and 69 kPa (5psig to 10 psig). The heat pump should be suitable for water or white water sources in the 55 C to 85 C range.

The demonstration installation would use water heated by steam from a Thermo Mechanical Pulping System. This will provide flexibility in terms of source temperature without influencing the pulp and paper process. The most important application would be heat recovery from white water from mechanical pulping processes. There are many other potential applications in the pulp and paper and other industries. This report should be read with an Canadian Electrical Association R & D Report titled "Potential of Electric Heat Pumps in the Newsprint Industry" (contract no. 124 U 291 by G. A. Robb Associates).

This heat pump, with a steam compressor, would allow upgrading of large quantities of heat from mechanical pulping in newsprint mills, boiler flue gas scrubbers, pulp and paper machine dryer hoods and other sources for use as process steam.

The heat pump would be shop assembled on a skid or platform for transportation as a module first to a testing and development facility, then to the pulp and paper mill. It is proposed in this report that the heat pump be demonstrated at the Port Alfred Newsprint mill of Consolidated Bathurst at La Baie, Quebec.

The alternatives considered were a larger scale R114 steam generating heat pump and a binary R114 - methanol system. The heat pump proposed here can be engineered and built by Canadian firms with decades of industrial refrigeration experience and access to Japanese high temperature heat pump technology. A larger unit would be beyond the current capabilites of these firms. As well, a larger steam generating R114 system is about to be demonstrated in Sweden. There is a requirement in Canada for the smaller units.

It is considered prudent to observe demonstration of the methanol heat pump already developed and built by Westinghouse before considering further methanol development. Developments in steam compression may eliminate the need for methanol heat pumps

The estimated cost of the heat pump exclusive of development costs and extraordinary engineering is $600,000. Estimated federal government expenditures is $1,230,000 over a period between 2 and 3 years.

The CEA study indicates that this technology can displace 5.4 million bbls. of oil equivalent, valued at roughly $160 million dollars per year, in the newsprint industry alone. Innovative (creative) financing techniques will be required to realize this potential.

Other potential benefits are an improved competitive position of the Canadian Pulp and Paper and other industries, and manufacturing, construction and engineering jobs.

## APPLICATION DE LA POMPE À CHALEUR R114 À GÉNÉRATION DE VAPEUR À LA RÉCUPÉRATION D'ÉNERGIE CALORIFIQUE DE MOYENNE TEMPÉRATURE DANS L'INDUSTRIE CANADIENNE DES PÂTES ET PAPIERS


### RÉSUMÉ À L'INTENTION DE LA DIRECTION

Il est proposé de faire le développement et la démonstration d'une pompe à chaleur R114 à génération de vapeur. Sa production serait environ de 16 GJ et la pression de la vapeur se situerait entre 34 kPa et 69 kPa (entre 5 lb/po$^2$ et 10 lb/po$^2$). La pompe pourrait fonctionner à partir d'eau ou d'eau blanche de température allant de 55°C à 85°C.

On se servirait pour la démonstration d'eau chauffée par la vapeur d'un triturateur thermomécanique, ce qui permettrait de faire varier la température de l'eau sans influer sur le procédé de fabrication de la pâte et papier. La plus importante application de la pompe serait la récupération de la chaleur de l'eau blanche des procédés de trituration mécanique. Mais il existe de nombreuses autres applications possibles dans l'industrie des pâtes et papiers ainsi que dans d'autre secteurs. La lecture du présent rapport gagne à être accompagnée de celle du compte rendu de R et D intitulé "Potential of Electric Heat Pumps in the Newsprint Industry" (contrat 124 U 291, G.A. Robb Associates) de l'Association canadienne de l'électricité.

La pompe, dotée d'un compresseur de vapeur, permettrait de récupérer de grandes quantités de chaleur que dégagent les triturateurs mécaniques des usines de papier journal, les épurateurs de gaz des chaudières et les hottes de séchage des matériels de pâtes et papiers, entre autres, et de produire à partir d'elles de la vapeur de fabrication.

Elle serait montée en atelier sur des patins ou une palette afin de pouvoir être transportée sous forme modulaire d'abord jusqu'à un centre d'essai et de développement puis jusqu'à une usine de pâtes et papiers. Il est proposé dans le rapport que la démonstration de la pompe à chaleur se fasse à l'usine de papier journal Port Alfred de la Consolidated Bathurst, située à La Baie, au Québec.

Deux autres possiblilités ont été envisagées, soit le recours à une pompe R114 de plus grandes dimensions et l'emploi combiné d'une pompe R114 et d'une pompe au méthanol. La pompe à chaleur proposée peut être conçue et fabriquée par des entreprises canadiennes qui possèdent des dizaines d'années d'expérience de la réfrigération industrielle et qui ont accès à la technologie japonaise du thermopompage à hautes températures. Ces mêmes entreprises ne sauraient toutefois actuellement réaliser une pompe plus grosse. La Suède est d'ailleurs sur le point de faire la démonstration d'un gros système R114 à génération de vapeur. Mais au Canada, c'est de petites pompes dont on a besoin.

Quant au système mixte au méthanol, on estime sage d'attendre les résultats de la démonstration de la pompe

à chaleur au méthanol que réalise la société Westinghouse avant d'envisager de quelconques travaux de développement, sans compter que d'éventuels perfectionnements des techniques de compression de la vapeur pourraient rendre tout à fait inutile le recours aux pompes à chaleur au méthanol.

Le coût estimé de la pompe à chaleur, à l'exclusion des coûts de développement et des frais extraordinaires d'ingénierie, est de 600 000 $. Les dépenses estimées du gouvernement fédéral sont de 1 230 000 $, sur une période allant de 2 à 3 ans.

L'étude de l'ACE indique que cette nouvelle technologie peut réduire la consommation d'équivalent-pétrole de 5,4 millions de barils par an (160 millions de dollars) dans la seule industrie du papier journal. Il faudra mettre en oeuvre d'astucieux programmes de financement pour réaliser ce potentiel.

Au nombre des autres avantages possibles de la nouvelle technologie on compte l'amélioration de la position concurrentielle de l'industrie canadienne des pâtes et papiers et d'autres industries ainsi que la création d'emplois dans les secteurs de la fabrication, de la construction et du génie.

## DEVELOPMENT AND DEMONSTRATION PROGRAM

The proposed Development - Demonstration program is based on a steam generating heat pump to be made in Canada for installation at the Consolidated Bathurst Port Alfred newsprint mill at La Baie, Que. The design will be suitable for steam generation using white water in the 60 C to 83 C range from mechanical pulping processes. This is the most important application for steam generating R114 heat pumps. An R114 steam generating heat pump would also be suitable using heat from paper machine hoods, boiler flue gas scrubbers, residual steam from multiple effect evaporators and other applications. The most likely demonstration application will use water heated by an existing system which recovers heat in steam from a thermo mechanical pulping system.

### Steps in the Program

1/Negotiation with operator to ensure that the heat pump will be demonstrated.

2/Completion of 2 comparative design-firm cost estimate contracts awarded to Canadian firms with strong industrial refrigeration backgrounds.

3/Selection of the firm to be awarded the contract for supplying the heat pump.

4/Investigation and selection of development facilities

5/Preparation of funding proposals

6/Completion of financial arrangements

7/Establishment of project team

8/Identification of development requirements.

9/Testing and development

10/Installation for demonstration in mill.

11/Reporting and monitoring for demonstration period

### Estimated Cost

Two Canadian firms with industrial refrigeration experience and access to high temperature R114 heat pump know how have provided estimating prices on the heat pump module. Based on that information, data on the cost of the Westinghouse methanol heat pump, and prices for high temperature hot water heat pumps, the conclusion is that the cost of the heat pump including engineering and some allowance for meeting a guarantee should be about $600,000 at the plant in Toronto.

The specification on which the estimating prices were based called for a heat pump to remove 10 million BTU/hr (10.55GJ/hr) from a 2000 USGPM (7570 litres/min) white water flow at 71 C (160 F), to generate 10 psig (69 kPa) steam. The output to be roughly 15 MBTU/hr or 15.8 GJ/hr.

**This capacity suites many applications such as Gatineau phase 2.** It is about as large a size as can be handled by existing Canadian suppliers of industrial refrigeration systems. For larger sources, units of this size can be staged to improve the overall COP.

A module approach was specified to minimize field work. An alternative to a module, which can be lifted onto a truck or flat car, is integration on a platform or a flat bed truck chassis for transportation to site.

With the platform approach, the building can be assembled at the factory so that the entire module, building included, can be moved to the site as though it were a mobile home. The trailer chassis is then removed and the building/heat pump module is lowered onto a concrete slab.

The estimating prices for the module excluded development costs. The estimated installed cost with a steam compressor, etc. is $1,317,000, using the above estimate for the heat pump module (see appendix B).

The mill demonstration will serve to identify development work which will improve performance of the heat pump. A detailed cost estimate for purchase of the heat pump, installation of the heat pump at the test site together with supply and installation of the test rig, assuming availability of electrical supply, is in appendix B. (The total including contingencies is $833,750 including $600,000 for purchase of the heat pump.)

The suppliers charge about $1,800 per week plus expenses for the services of technicians - say $2,500 per week including expenses. If two supplier technicians were to be involved for four weeks, that would cost $20,000. Electricity to operate the system would cost about $6,700 if it were to operate 40 hours/week for 4 weeks.

**Applications**

Applications have been studied at the Consolidated Bathurst Port Alfred mill at LaBaie, Que. where only part of the heat from a TMP system is being used to preheat air and water in winter ; the Consolidated Bathurst mill at

Grand'Mere, Que.; the CIP Inc mill at Gatineau (phase 2 of the heat pump system now in place); the Mason mill of James MacLaren; Kruger's Trois Rivieres mill; and the Abitibi Mission mill at Thunder Bay.

Cost estimates and profitability analysis have been completed for the Port Alfred application, the Gatineau application and a system which could be installed in Grand'Mere or the Kruger mill at Trois Rivieres. The system suitable for Grand'Mere or Kruger Trois Rivieres was analysed to illustrate how, using two heat pumps and a single steam compressor, improves economics.

Any of these applications would be satisfactory and there are others. Consolidated Bathurst have been interested in heat pumps for many years. They performed the tests which demonstrated that, providing the velocity is kept high, it is practical to use white water as a source for a heat pump with a shell and tube evaporator. The tests were at their Grand'Mere Research Center, which is at a mill with unusually high system temperatures.

The Grand'Mere application is particularly interesting and significant. The Consolidated Bathurst mill has a very well "closed" white water system. This means a large fraction of the water is recycled. Because of this, system and effluent temperatures are high.

The system temperatures at Grand'Mere were too high in summer. To avoid adding fresh water to cool the white water, a shell and tube heat exchanger was installed. It plugged up. They found a spiral heat exchanger to be satisfactory.

The Department of Energy, Mines and Resources (G. A. Robb) and Hydro Quebec (Gaston Boucher) became aware of this heat pump opportunity via Canadian Pulp and Paper Association, Technical Section Activities. Consolidated Bathurst agreed to investigate solutions to the plugging problem. Following visits to Grand'Mere and the Westinghouse research center in Pittsburgh, it was decided that Consolidated Bathurst would undertake a test program to explore possible modifications to a Templifier evaporator to avoid plugging with groundwood white water. C. B. would work with PPRIC who would submit a proposal to EMR for

funding. G. A. Robb, then with EMR, guided the proposal through the system and became scientific authority. The results of this program were presented at the 1983 CPPA/Japanese TAPPI International Energy Conservation Conference in Ottawa (p79 of preprints) by M. K. Azarniouch of PPRIC and Y. Lemay of Consolidated Bathurst Grand'Mere Research center. These results are also contained in a report prepared under contract to Supply and Services Canada, Contract Serial no. 1 SQ 79-00080, DSS File no 23 SQ 23380-9-6335.

That program provides important background for the program proposed here. The test work was done by Consolidated Bathurst, specifically to determine the the appropriate evaporator geometry for a steam generating heat pump supplying paper machine dryers and using groundwood white water as a heat source. This is the most important application for the steam generating R114 heat pump.

The PPRIC/CB report discusses a heat pump application and provides a useful analysis of the source flow and temperature. It is based on the assumption that the source leaving temperature is 71.4 C (160.5 F) and generates steam at 440 kPa and 147.2 C (50 psig and 297 F).

Because of this early effort by Consolidated Bathurst, G. A. Robb Associates approached them to discuss a demonstration for the steam generating R114 heat pump. The contract with NRC was explained to them in a letter. A positive response took the form of a letter from Mr. J. P. Woods, Vice President of Manufacturing - see appendix D.

As noted in the letter, Mr T. E. Savoy, Chief Engineer of Consolidated Bathurst is co-ordinating the work for that company. G. A. Robb & H. J. Barton met with Mr. Savoy and Rod Meares to discuss possible applications for the steam generating R114 heat pump.

Mr. Savoy proposed an application at the Pt Alfred Division in La Baie, Que. There is a Thermo Mechanical Pulping (TMP) system in the newsprint mill with a heat recovery system producing hot water. With some modifications to the heat recovery system, the hot water can be used as a source for the steam generating R114 heat pump.

This provides an ideal opportunity to demonstrate a newly developed heat pump because the heat source is not a process stream. The temperature and flow can both be changed without influencing the process in any way.

The origin of the heat to be upgraded is a TMP system which converts wood chips into pulp.

Steam is generated between pairs of disks. The face of each disk is covered with grooved plates. One disk is fixed and the other is rotated by a large electric motor. The electrical energy is converted to thermal energy by the pulping process. Some appears as heat in steam and some as heat in the water/fibre mixture (pulp). After 2 stages of refining, the pulp is diluted to the point where it is mostly water (roughly 1% fibre). It goes through a screening and cleaning system to a disc filter (thickener). From the thickener pulp at perhaps 3% consistency (3% fibre) goes to the paper machines. The white water removed by the thickener is a potential 71 C (160 F) heat source, ideal for a steam generating R114 heat pump in the future. That heat now helps maintain system temperatures. The fraction of the electrical energy input which appears as steam depends on the consistency entering the refiner, the amount of water added in the refiner and consistency leaving the refiner. Less water means a large steam fraction. A large fraction of the steam can be captured, but there will be some lost.

The Port Alfred TMP system consists of a steaming tube, 2 primary refiners operating at 25 psig and 2 secondary refiners operating at atmospheric pressure. Currently steam from all four refiners goes to the recovery system producing warm water.

Steam from a refiner flows in 2 directions - forward flow steam is mixed with the pulp leaving the refiner. Backflow steam flows counter to the pulp entering the refiner.

At Port Alfred, forward flow steam from the pressurized primary refiners flows through blow valves to an atmospheric cyclone which separates it from the pulp. Back flow steam from the primary refiners is separated from the pulp as it leaves the refiner and flows to the steaming tube. Surplus steam from the steaming tube flows to the recovery system. Backflow steam from the secondary refiners goes to the heat recovery system.

Forward flow steam from the secondary refiners flows with the pulp to the chest where it mixes with air. The air makes it a less satisfactory heat source.

Base Case

The demonstration will use water from the existing recovery system. As a base case it is assumed that steam from both primary and secondary refiners will continue to go to that recovery system. There is far more available than the 10 million BTU/hr (10.55 GJ/hr) required for the demonstration.

The heat recovery system consists of an indirect water heating system supplying water for wet end showers via a plate type heat exchanger; an air heating section, and sprays for direct water heating.

To provide a circulating flow of roughly 2000 USGPM (7571 L/min.) at about 160 F, additional spray headers should be installed where the temperature is highest. A circulating system with a pump will be required.

The steam from the primary refiners contains very little air and is roughly 212F (100C). The backflow flow steam from the secondary refiners contains some air by the time it reaches the recovery system. At the point where it leaves the refiners it was in the 200 to 212 F (93 to 100 C) range at the time of the G. A. Robb Associates study. The air infiltration between the refiners and the recovery system can be largely eliminated with little effort. A lot of air is added to the forward flow steam from the secondary refiner as it passes through the chest. That will not be a problem with the base case because there is far more heat available than is required for the demonstration.

When a conventional steam recovery system for the pressurized refiners is installed, and only steam from the secondary refiners is available for the heat pump, some modifications will be required to capture at least some of that steam without much air.

The engineers at the mill have selected a location just outside the TMP building for the heat pump. Thus a module built on a platform with the building to be moved like a mobile home would be appropriate. The location is near both the steam plant and the paper machines so the steam could be used either for feedwater heating or for the paper machines.

Because centrifugal compressors are thoroughly proven, the base case calls for an Atlas Copco Turbinetics SC 10 centrifugal compressor (or equivalent) with a 500 horsepower motor. The 10 psig (69 kPa) steam from the heat pump would be boosted to 35 psig (241kPa) so it can be piped to the paper machine dryers. This will demonstrate the use of water at about 71 C (160 F) to generate steam for paper dryers.

**Profitability**

Because there is no experience with steam generating R114 heat pumps, sensitivity analysis is the focal point of the profitability analysis. Appendix A contains profitability data for a variety of assumptions. Page 1 of Appendix A is a summary for 3 cases. Pages 2 to 26 of Appendix A show 11 years of cash flows and 20 year internal rates of return for a variety of combinations of assumptions. Page 3 shows the effect of assuming maintenance cost to be $20,000 in the first year of operation as compared with $5,000 on page 2. Page 4 shows the effect of capitalizing $50,000 of first year extra ordinary operating and maintenance costs and expensing $20,000 of regular maintenance costs. Page 5 could be interpreted to show capitalizing $100,000 of extraordinary first year costs or a cost overrun of $100,000. All pages except pages 6 and 8 assume 8,000 operating hours per year. Page 6 shows the effect of assuming more down time due to problems with either the source or the heat pump system resulting in only 7,000 operating hours per year. The total number of hours per year is 8760. Thus most cases assume 9% down time and page 6 assumes 20% down time.

The other pages in appendix A are self explanatory. In all cases an electrical cost increase of 6% per year has been assumed. (see letter from W. G. Keller of Ontario Hydro, page 29, Appendix A).

Assuming an oil price of $28/bbl for heavy fuel oil and $.017/kwh, electricity, the after tax internal rate of return is 24.2%. Heat pump installations qualify for a 25%, 50%, 25% straight line capital cost allowance under class 34. A regional investment tax credit of 10% has been assumed.

The investment tax credit must be deducted from the capital cost in calculating the capital cost allowance (CCA). No grant has been assumed.

If the oil price is assumed to be $26/bbl and the electricity cost $0.017/kwh, the 20 year internal rate of return is 21%. With an oil price of $31/bbl and the same electrical cost, the 20 year after tax internal rate of return is 27.3%.

In calculating the internal rate of return, the investment tax credit was treated as a reduction in capital cost. The alternative would have been to include it in year 1 positive cash flow and not deduct it from the capital cost. The difference in result is small. Either the before tax or the after tax payback can be determined from the cash flows for each case.

The economic potential is better illustrated by a case using 2 heat pumps and a single steam compressor. Such a scheme could be used in almost any newsprint mill using white water directly from mechanical pulping processes. The after tax internal rate of return with $31/bbl. oil and $0.02 electricity is 33%. For the base case, the after tax IRR of about 24% would be interesting if the technology were fully proven and there were not more attractive uses for the limited amount of corporate capital.

At this stage there is uncertainty about the capital cost, maintenance cost and the fuel price. The electricity for Port Alfred is from hydro facilities owned by ALCAN and the province insists that they sell to other industries at very low rates. There does not appear to be much risk that electrical rates will increase more than anticipated in the analysis.

**Design/Development Phase**

It is proposed that contracts for detailed design and firm cost estimates be awarded to 2 potential suppliers. This should be limited to Canadian firms with years of experience in designing industrial refrigeration systems, manufacturing evaporators and condensers for these systems and integrating the systems into shop assembled modules which can be lifted onto trucks or flat cars for transportation to the site. A further prerequisite should be established industrial refrigeration system start up and service facilities capable of dealing with installations anywhere in Canada.

The 2 design contracts will be based on a specification which will allow the potential suppliers scope for initiative in designing the heat pump

module. Cost estimates will be required for each design. Development requirements should be dealt with in the reports submitted by the potential supplier in meeting the contract requirements. General arrangement drawings and other information required to evaluate the design should be provided.

If a firm is strongly motivated to add industrial heat pumps to their product line, they will invest some of there own funds in the design phase. This should be considered in deciding how much to pay each of the 2 firms.

During the design phase, there will be an effort to thoroughly familiarize the potential suppliers with the demonstration application and the other potential applications for R114 steam generating heat pumps. Following the design phase, either firm should be in a position to bid on steam generating R114 heat pumps or industrial hot water heat pumps. While only one of the 2 firms can be selected to supply the demonstration unit, both would profit from the entire program.

After the designs have been studied, the supply contract could be awarded to the firm offering the best combination of capability, price and design. Alternatively a more precise specification could be sent to the 2 potential suppliers and they could be asked to bid on that.

It is important that the demonstration heat pump be tested and satisfactory operation proven before it is installed in a mill. This will avoid "giving the technology a bad name". It is unlikely that the pulp and paper company will become financially involved until they have seen the unit running.

The minimum performance tolerance to guarantee ultimate installation of the heat pump at the mill, should be considered mainly in terms of reliability. Concern that down time might be excessive would be the main deterrent to installation at the mill. This is discussed at the end of this section.

**Test/Development Facilities**

The development phase will require a test facility capable of supplying about 1400 kw. The facility would consist of a tank, piping & a circulating pump. A pump would circulate the 2000 USGPM through the evaporator & back to the tank. Steam from the heat pump would maintain the source temperature.

The source of feedwater would depend on the location of the test facility. If condensate or treated feedwater is not available, chemicals to prevent scale and corrosion would be added to raw feedwater.

It would be a great advantage for the heat pump supplier to have a facility capable of testing a heat pump this size. The supplier of Templifiers, for example is capable of testing units with this electrical requirement. Helping the supplier finance a test facility is one option. Ontario Hydro might be interested in helping with the electrical supply.

Chalk river would seem to be a logical place to test heat pumps. They are well equipped with pumping facilities, measuring equipment etc.

Apparently electrical supply is the problem at NRC. Perhaps the testing could be done at the low temperature lab during periods when everything else is shut off although that may not be practical.

The Hydro Quebec R & D facilities are another possibility.

The possibility of doing the testing and development at the mill has been considered. These days pulp and paper mills operate with a a minimum of staff. It is important to avoid giving the technology a bad name. There is a strong case for doing the testing and development before the heat pump is delivered to the mill. The mill will no doubt have enough trials and tribulations with the heat pump/steam compressor combination during the initial operating phase.

**Scheduling**

Two to 3 months should be allowed for study and design to ensure all the necessary know how is acquired, the heat exchangers are optimized etc. The suppliers suggest 12 to 16 weeks for delivery from the time the design is complete but that may be optimistic. It would be advantageous to do the testing before freezing temperatures are encountered in late 1984 but it may be difficult to achieve that. If the "mobile home approach" to the heat pump ,module is used, cold weather would be less of a problem but the tank and circulating system would not be in the heat pump building. In any case Consolidated Bathurst would budget for 1985 installation.

**Government Funds Requirement**

The case for government financial assistance is founded on four arguments.

1/ A testing and development program before the heat pump is installed at the mill to avoid damaging the reputations of the technology or the supplier.

2/The risk that excessive down time, particularly during the early months or years of operation will reduce the savings.

3/The fact that, because the pulp and paper companies have so many other ways to spend money, they will not consider this technology until they can observe successful operation.

4/ The risk of a capital cost overrun because the technology is new.

Page 8 of Appendix A illustrates the effect of excessive downtime. That analysis is based on the assumption that the system operates only 4,000 hours per year, but a 50% grant reduces the capital cost. It should be noted that according to the income tax regulations, the grant must be deducted from the capital cost used for determining the Capital cost allowance for income tax purposes. There are 8760 hours in a year and the other cases in the sensitivity analysis assume 8,000 hours of operation per year.

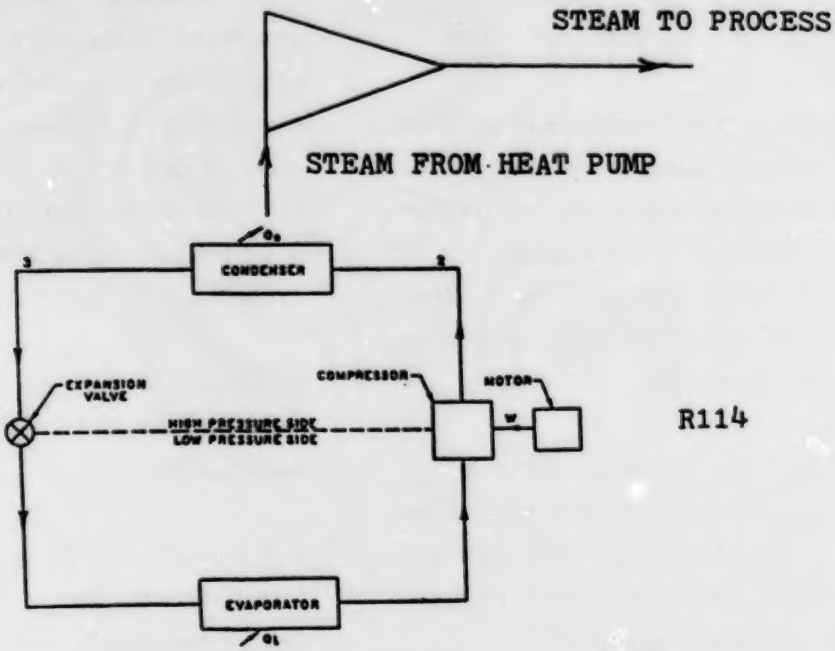
That would amount to $790,000. The cost estimate (appendix B) for temporary installation of the heat pump at the test facility, required for the testing and development program prior to delivery to the mill, indicates $125,000 if the cost of the heat pump is subtracted and a 15% contingency is excluded.

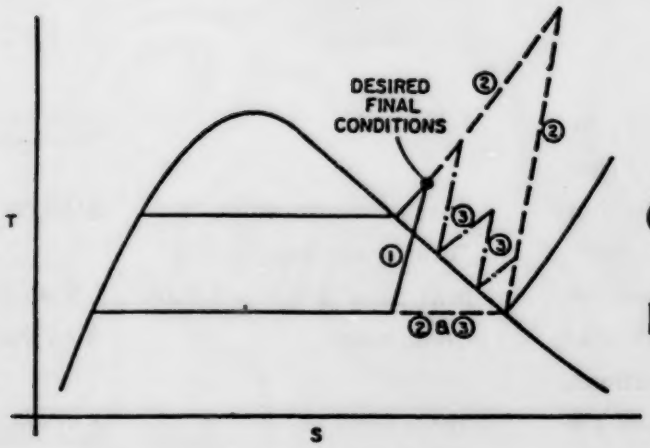
If $25,000 is paid to each of the 2 potential suppliers, $50,000 would be required for that.

| | |
|---|---|
| Purchase of heat pump and installation for test | $833,000 |
| Design contracts | $ 50,000 |
| Test technicians | $ 27,000 |
| Consultants | $ 15,000 |
| Total 1984 | $925,000 |
| Cost of monitoring | $100,000 |
| Total grant less cost of heat pump $790k - $ 600k = | $190,000 |
| Consultants | $ 15,000 |
| Total 1985 | $305,000 |

(Assumes detailed engineering by mill)

STEAM COMPRESSOR




STEAM COMPRESSION PATHS

① DIRECT COMPRESSION OF TWO-PHASE MIXTURE TO DESIRED CONDITIONS

② DIRECT COMPRESSION OF DRY SATURATED STEAM TO DESIRED PRESSURE FOLLOWED BY LIQUID INJECTION TO DESIRED TEMPERATURE

③ MULTI-STAGE COMPRESSION WITH INTERSTAGE LIQUID INJECTION

THERMOELECTRON

**Figure 1 Equipment diagram for heat pump system.**

## DESCRIPTION OF HEAT PUMP SYSTEM TO BE DEVELOPED

A 16 GJ heat pump using R114 as a working medium and capable of producing steam at 14 to 69 kPa (2 psig to 10 psig) should be developed for use with or without a steam compressor. The combination will be used to upgrade heat from sources in the 55 C (130 F) to 95 C (200 F) range to generate process steam. The upper limit of steam pressure/temperature will depend on the fuel price/electrical price relationship. It is likely to be less than 483 kPa (70 psig). For low pressures a steam jet compressor could be used.

### Basic Components

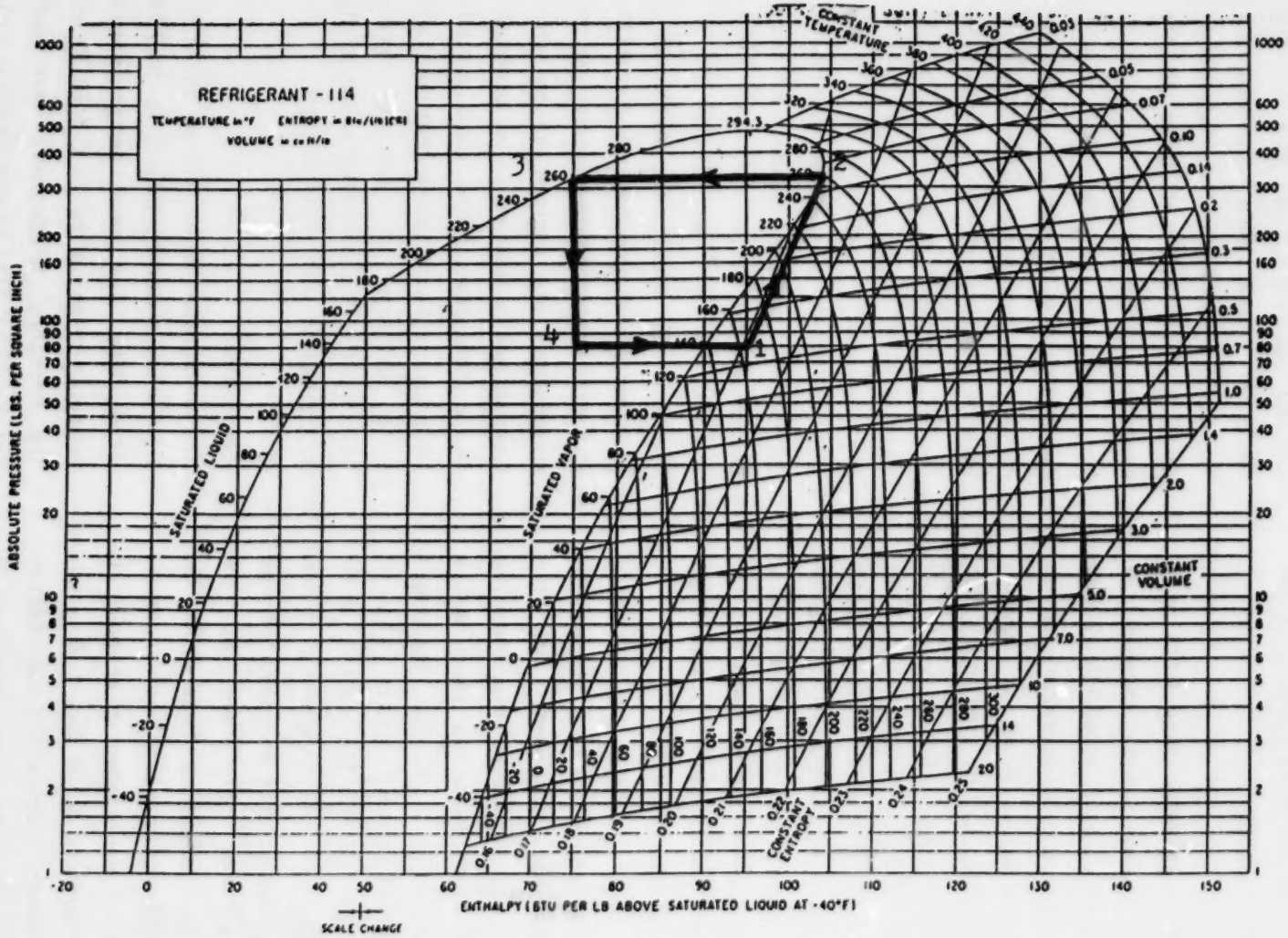
The principal components of the proposed system are an evaporator, a compressor, an expansion valve and a condenser. Fig 1 is the equipment diagram for the basic vapour compression cycle. The source water flows through the evaporator tubes. Refrigerant 114 evaporates and superheats in the shell of the evaporator, absorbing heat from the source. The R114 leaves the evaporator enroute to the condenser at point 1. The compressed R114 (point 2) enters the condenser tubes where condensation and subcooling take place. Feedwater is supplied to the shell side of the condenser where steam is generated. The liquid freon leaves the condenser at point 3 from which it flows to the expansion valve.

Steam and other refrigerants, superheat as they are compressed. R114 does not so some superheat is usually added prior to the compressor. At the condenser R114 pressure/temp. level, the latent heat available for rejecting heat is less than the latent heat at the evaporator. Subcooling in the condenser helps compensate for this.

Fig 2 is the ideal basic cycle on a pressure - enthalpy diagram for R114. Pressure losses and heat losses to the surroundings are assumed to be zero. Compression is assumed to be isentropic in the ideal case. There would actually be pressure losses, some heat loss and some increase in entropy during compression. The numbered points in fig 2, correspond with those in fig 1.

### Evaporator

The evaporator is to remove 10.55 GJ from white water containing up to 0.1% wood fibre. The basic design source temperature should be 71 C (160 F) but the operating temperature may vary between 63 C (145 F) and 74 C (165 F).

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Pressure-Enthalpy Diagram for Refrigerant 114

**Figure 2** Ideal cycle for steam generating, R114 heat pump: 1-2 Compression; 2-3 Condensation; 3-4 Expansion; 4-1 Evaporation.

The velocity of the source water in the tubes should be kept well above 1.8 meters (6 ft) per second (6 ft/second) to avoid plugging. The tube material should be 316 stainless steel to avoid corrosion. In designing the evaporator, the results of the R & D program undertaken by Consolidated Bathurst and the Pulp and Paper Research Institute of Canada at Grand'Mere should be considered. That program was funded by the Federal Department of Energy, Mines and Resources and reported under DSS contract serial no 1 SQ 79-00080, DSS file no 23 SQ 23380-9-6330. As well, experience with the evaporator of the Templifier heat pump at the CIP Inc. Gatineau mill should be considered.

Most potential sources for industrial heat pumps are contaminated. In many cases, solids in the sources introduce the risk of plugging and fouling of the heat transfer surface. Slime (bacterial growth) can be a problem. Maintaining high velocity reduces the risk of fouling and plugging. It also improves heat transfer by reducing the thickness of the boundary layer.

Other solutions to plugging and fouling problems involve heat transfer surface geometry. Lamella heat exchangers and spiral heat exchangers are examples.

Future R & D should deal with the use of these different shapes for industrial heat pump evaporators. For this project, a shell and tube evaporator with the source in the tubes is recommended. This will suite most sources, tubes can be cleaned by flow reversal using brushes or balls and there is less risk of distortion due to pressure than with other shapes.

Strait tubes should be used. Multipass configurations can be achieved by using divided water boxes or heads. Heads should be removable to allow cleaning.

Compressor

Industrial refrigeration systems of the size appropriate for this project generally use either oil flooded screw compressors or centrifugal compressors. Screw compressors develop more pressure per stage but the presence of oil is a disadvantage. It would appear that the advantages of screw compressors for smaller steam generating R114 heat pumps justify the development of a system which uses them. A heat pump module with an output of 15.8 GJ (15 million BTU/hr or 4.4 MWT) would suite the capabilities of Canadian suppliers of industrial refrigeration systems.

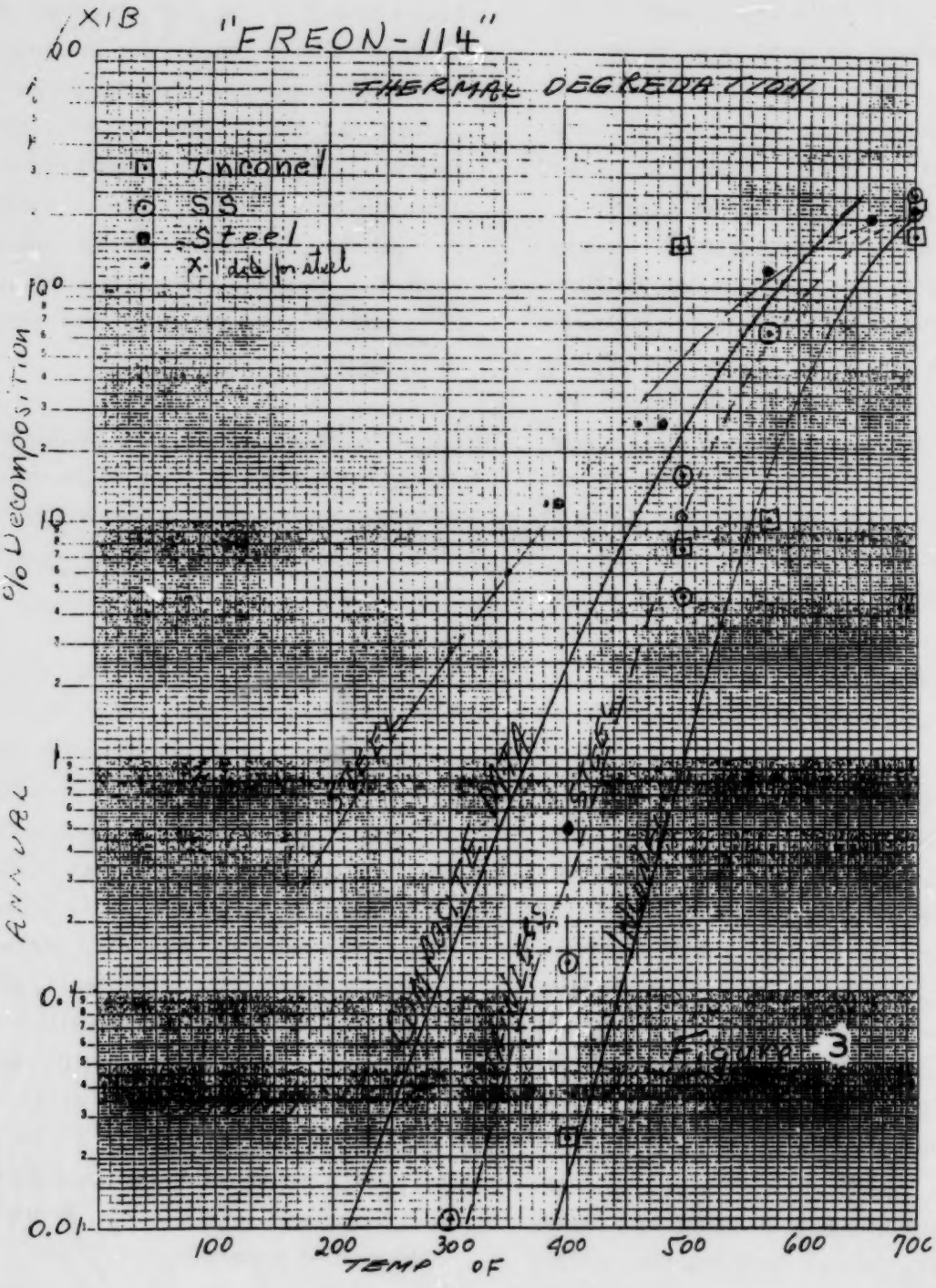



**Figure 3** Curves showing rate of degradation vs. temperature for R114.

Such a module size would be appropriate for many applications. Canadian designers & manufacturers of industrial refrigeration systems, have said they would use oil flooded screw compressors for a steam generating heat pump of this size. Oil flooded screw compressors are being used in industrial heat pumps heating water to just above the atmospheric boiling point in Sweden and Japan. Thermal degredation of the R114 has not been a problem despite the presence of oil.

It should be possible to design an open drive centrifugal compressor for an R114 heat pump without any mixing of oil and R114. A Swedish firm is using centrifugal compressors but oil is used for the seal and some oil does mix with the refrigerant.

Thermal Degradation

Fig 3 shows rates of thermal degradation vs temperature for pure R114. The saturation temperature of steam at 69 kPa (10 psig) is 116 C (240 F). If the R114 temperature is 10 to 15 deg F higher than the saturated steam temperature there would be negligible thermal degradation with stainless steel and very little with carbon steel. When oil is mixed with the freon, there is some degradation of the oil at these temperature levels.

The presence of oil apparently accelerates thermal degradation of the R114.

Experimental data from Japan indicates that steam can be generated at 34 kPa (5 psig) with no evidence of thermal degradation and at 69 kPa (10 psig) with a manageable rate of thermal degradation of oil and R114. Selection of the proper oil is critical.

There is a Swedish group in the early stages of a steam generating R114 heat pump/steam compressor development & demonstration program using centrifugal compressors. That group owns a company with a large industrial heat pump user list including units using R114 with oil flooded screw compressors at temperatures high enough for steam generation. Another company in the same group has developed heat pump capability as an adjunct to a highly successful industrial steam and gas turbine activity. This company is developing a steam generating R114 industrial heat pump to be demonstrated in a Swedish Pulp and Paper Mill.

This company makes large heat pumps for district heating systems and has developed a line of centrifugal

compressors for them. They will use their centrifugal compressors for the steam generating R114 unit.

The Swedish steam generating R114 heat pump technology should be made available in Canada via arrangements with a Canadian company capable of making the heat exchangers. There is a strong case for NRC helping that company (not yet selected) with research and development work aimed at adapting the Swedish Technology to Canadian applications.

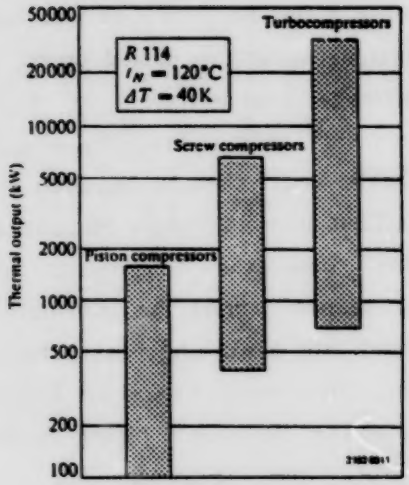
The only two Canadian companies, with long established engineering and manufacturing capability in industrial and marine refrigeration, use Japanese oil flooded screw compressors. They have access to Japanese heat pump technology. As was discussed in another section, the first phase of the recommended development program involves awarding 2 design contracts to qualified firms. The qualified firms should be allowed to select the compressors.

There appears to be a general tendency to use reciprocating compressors for small heat pumps, oil flooded screw type compressors for medium sized heat pumps and centrifugal compressors for large heat pumps. Except for the fact that reciprocating compressors are used in very small units and centrifugal compressors in very large units there are no hard and fast rules.

There is an 8 MWT (27 million BTU/hr or 28.8 GJ/hr) heat pump using an oil flooded screw compressor in Sweden. There is a 40 MWT (136 million BTU/hr or 136 GJ/hr) at Malmo in Sweden using a centrifugal compressor. There are U. S. made heat pumps (Templifiers) using centrifugal compressors and having outputs as low as 1.2 million BTU/hr (1.26 GJ/hr or 351 kw).

Screw type heat pumps are positive displacement machines and a single stage can develop a large pressure ratio. To develop large pressure ratios, centrifugal compressors must be run at very high speeds. They can be multistaged. As a general rule screw compressors probably have an advantage in smaller sizes where large pressure ratios are required. With oil flooded screw compressors control is achieved with an internal recirculation scheme. Inlet vanes are generally used with centrifugal compressors.

In an article in the Sulzer Technical Review (3/82 p.22) on High Temperature Heat Pumps, H. J. Bauder of Escher Wyss, suggests that, where R114 is the working medium, the range for reciprocating compressors is up to just




Performance ranges
for compressors SULZER

under 2 MWT (6.8 million BTU/hr or 7.2 GJ/hr); for screw compressors from 500 kw (1.7 million BTU/hr or 1.8 GJ/hr) to about 6 MW (20 million BTU/hr or 21.6 GJ/hr); and for centrifugal compressors from just under 1 MWT (3.4 million BTU/hr or 3.6 GJ/hr) to more than 30 MWT (102 million BTU/hr or 108 GJ/hr). He points out that one of the great advantages of R114 is the fact that it is compatible with oil (it is soluble in oil). He notes that because compressor lubricants can operate at up to 150 C and the upper limit for R114 is generally considered to be about 130 C, that oil free operation of R114 compressors is not necessary.

Bauder notes that where the ranges overlap, oil flooded screw compressors are taking over from reciprocating compressors. Given the fact that the only 2 Canadian companies with substantial industrial refrigeration experience use oil flooded screw compressors, there is a strong case for helping them develop a steam generating R114 heat pump based on that technology. They would compete in the Canadian market where units up to about 16 GJ/hr are required.

For larger capacities, Swedish and possibly Swiss technology via joint ventures with Canadian companies can meet the requirement. There is a case for NRC helping a Canadian joint venturer adapt the Swedish technology to Canadian conditions.

**Condenser/Boiler**

Industrial high temperature heat pumps generally use condensers with water flowing through the tubes and R114 condensing on the shell side. In the case of a steam generating heat pump, the R114 should probably condense inside the tubes with water boiling on the shell side.

Among the options are submerged, horizontal tubes and natural circulation, forced circulation with water sprayed over horizontal tubes, a vertical configuration with R114 condensing inside the tubes and forced circulation boiling outside the tubes. Discussions with the Westinghouse R & D people in Pittsburgh who designed the 30 million

BTU/hr methanol heat pump considered these options and decided on boiling in the shell with a submerged tube horizontal arrangement.

They say that is considerably less expensive than forced circulation designs.

The condenser/boiler is the only component of the system not roughly the same as in the industrial refrigeration systems now being designed in Canada. The refrigeration companies also make heat exchanger packages for other purposes and designing a condenser boiler should not be too difficult for them. Optimizing the design will require a good deal of time and effort. The result should be much better if they are awarded design contracts prior to being asked to bid on supply of the systems.

The boiler should be designed to avoid carry over of water. The water could damage the compressor. A great deal of development work aimed at avoiding water carryover has been done by the boiler industry. Collaboration with a boiler supplier is a possibility.

**The Heat Pump Module**

The heat pump should be completely assembled on a skid in the shop, or on a platform. The skid would be lifted by a crane onto a flat bed truck or flat car. The platform would be jacked up on to a truck/trailer chassis for transportation to the site. The chassis and wheels would then be removed and the platform lowered onto a foundation. In either case the components and control system should be completely integrated into a working heat pump in the shop. Field work should be limited to connecting the source piping to the evaporator, the feedwater to the condenser/boiler, the steam to the boiler outlet; and the electrical connections.

**Design Steam Pressure and Flexibility**

There are likely to be variations in source temperature, and in some cases source flow. In most cases the steam pressure from the heat pump condenser - boiler should be roughly constant. It should remain above atmospheric pressure. The condensing temperature of the R114 must remain below a predetermined level above which thermal degradation would be difficult to manage. The level is less than 130 C. One of the advantages of R114 is that is does not superheat when it is compressed. Thus, condensing temperature should be the maximum to which it is subjected. This must be high enough to provide delta T for heat transfer. The saturation temperature of 10 psig (69 kPa) steam is 115 C (240 F).

The saturation temperature of 5 psig (34.5 kPa) steam is 108C (228 F). There must be enough temperature difference to transfer the heat through a reasonable amount of surface. This differential should likely be from 3 C to 9 C.

Research with oil flooded screw compressors in Japan indicated that thermal degradation is not a problem at the condensing temperature required for 5 psig steam. There is evidence of degradation of both oil and R114 at the condensing temperature required for 10 psig steam but the rate appeared to be manageable.

There is significant advantage in 10 psig capability. A single stage centrifugal steam compressor can upgrade 10 psig steam to 35 psig steam (69 kPa to 241 kPa). Most newsprint dryer sections can use a lot of 35 psig steam. If the heat pump develops only 5 psig steam, a single stage steam compressor could develop 25 psig or 173 kPa. While many newsprint machines can use 25 psig steam, some cannot.

If the heat pump is designed to be capable of operation at either 5 psig (34.5 kPa) or 10 psig (69 kPa), a lot can be learned about the practical upper limit for R114 with an oil flooded screw compressor. If after a period of 6 months to a year of operation at 69 kPa, thermal degradation appears to be a problem, the heat pump can be operated with an output steam pressure of 35 Kpa or 5 psig to avoid the degradation problem.

If a water flooded screw compressor is used, and the heat pump develops only 5 psig, the compressor could deliver more than 85 psig (586 kPa), although that pressure is not required and rarely be economic. There is much less experience with water flooded screw type steam compressors and there is some doubt as to whether it would be logical to introduce the additional uncertainty of that technology with the first steam generating R114 heat pump.

Centrifugal compressors with Titanium impellers capable of developing more than a 2 to 1 absolute pressure ratio in a single stage have recently become available.

The base case calls for a heat pump generating 10 psig steam teamed with a single stage centrifugal compressor to generate 35 psig steam.

Further investigation during the detail design phase could indicate that the heat pump should generate lower pressure steam. One alternative would be to operate the heat pump for say 1 year without a steam compressor, verify the 10 psig steam capability and then select the compressor. For that period a steam jet thermo compressor could be used instead of the electric drive mechanical compressor. The steam jet would require about 2 pounds of motivating steam per pound of entrained steam so it is not a good long term solution. The motivating steam would crowd out steam from future TMP steam recovery systems. An alternative would be to use the steam for feedwater heating for the trial period.

Assuming the demonstration mill to be Port Alfred - La Baie, further investigation will probably reveal that 25 psig steam can be used in the dryers so if the heat pump steam pressure must be lowered to 5 psig, the single stage centrifugal compressor would be satisfactory.

Source Variations

As noted, the source flow and temperature will vary in many cases. One of the questions to be answered during this development/demonstration program is the degree of variation which can be tolerated while maintaining steam pressure at an appropriate level. The detail design phase should shed a lot of light on this.

The Port Alfred application should allow adjustment of the source temperature.

Source temperature variation will be a more serious problem with a steam generating heat pump than in cases such a heating feedwater makeup where the temperature of the water being heated is not critical. If the process operating people will co-operate, it should be possible to keep the source temperature within specified limits. There would probably be some cost associated with that. The cost would be either in terms of additional operator effort or additional control hardware. The 140F to 165F capability is desireable if it does not cost too much in terms of heat pump cost or heat pump performance. Some of the flexibility can be achieved via the steam compressor

The recommendation is that in the design phase, a heat pump capable of dealing with source temperatures in

the 60 C to 74 C range be considered, and the cost and performance of that be compared with a design based on a source temperature range from 65 C to 71C.

Those awarded design contracts should be asked to report at some length on the flexibility question.

The Control System

In most cases the demand for steam will exceed the supply available from the heat pump (heat pump capacity) by a wide margin. If the steam is to be used in paper machine dryers, pressure control will be by a controller operating a valve from the main mill steam supply. If the line from the steam compressor is connected directly to the paper machine dryer header, the pressure will change to control the moisture level in the paper. For the paper dryer application, this is the method which would maximize the COP and minimize the electrical requirement.

An alternative is to supply the steam from the heat pump/steam compressor combination to a constant pressure header supplying the paper machines. This header may be at 50 psig in which case there would probably be some unnecessary electrical energy used to boost the pressure to a level higher. The 50 psig header alternative is available only in certain mills.

In cases where the pressure varies, at least part of the control can be via the steam compressor. If a centrifugal steam compressor is used, inlet vanes will likely provide the control. Additional control could be provided by the heat pump. If the heat pump uses an oil flooded screw compressor, the control will be via an internal recirculation arrangement.

If a screw type steam compressor is used, the only efficient control mode appears to be variable speed. One approacn is to use 2 half size compressors. One would have a variable speed drive and the other a fixed speed drive. This scheme was proposed by a water flooded screw type steam compressor supplier. The smaller variable speed drive would cost so much less than would a full sized variable speed drive that the difference would offset the extra cost of the two compressor approach.

In the design phase, the potential suppliers should thoroughly study control system options in a effort to develop an approach flexible;e enough to accommodate process changes.

## THE CASE FOR DEVELOPING A STEAM GENERATING R114 HEAT PUMP

Industrial vapour compression heat pumps now available use refrigerant R114 and will deliver hot water at up to 110 C (230 F). They do not generate steam. The Templifier, the most widely used industrial heat pump, is a hermetic unit. The motor is cooled by the refrigerant and the source leaving temperature must be limited to about 55 C (130 F). Thus, while the hot water could be used to generate steam in a flash boiler, the Templifier cannot handle source temperatures suitable for steam generation. An open drive vapour compression heat pump to generate steam directly will meet a wide range of industrial process steam requirements.

### Open Cycle Heat Pumps - Steam Compressors

Steam compressors are now the best means of upgrading heat from temper- atures above the atmospheric boil- ing point of water. For lower tem- perature sources, a steam generating R114 heat pump/steam compressor combination could meet industrial process steam requirements.

Steam compressors or open cycle heat pumps have been used for vapour compression evaporation for many years. The first TMP heat recovery system at Halstavick in Sweden used a Sulzer steam compressor. Among the long established steam compressor suppliers are Allis Chalmers, Sulzer Ahlstrom Atlanitque and Dresser.

Within the past few years, Mechanical Technologies of Albany, N.Y. have developed a centrifugal steam compressor capable of a 2 to 1 absolute pressure ratio in a single stage. A separate company, Atlas Copco Turbinetics was established to manufacture and sell that design.

Originally a joint venture, (Atlas Copco/Mechanical Technologies), Atlas Copco Turbinetics is now owned by Atlas Copco. They have recently made units with titanium impellers available. These are capable of pressure ratios in excess of 2 to 1 in a single stage.

Another recent development is the screw type steam compressor. Thermo Electron, Atlas Copco and Mycom all produce units capable of absolute pressure ratios of 5 or more in a single stage. The screw compressor becomes competitive with the

centrifugal unit at pressure ratios of 3 or more.These new developments have reduced the cost of open cycle heat pumps. In many cases the cost is now from one half to one third the previous level.

**Methanol Heat Pumps vs Steam Compressors**

One school of thought has held that a new high temperature refrigerant is required for heat sources in the 82 C (180 F) to 126 C (258 F) range. The upper end of this range corresponds with a steam pressure of 138 kPa (20 psig). Below that level the specific volume of steam entering the compressor is too high for steam compressors, according to that school.

This position was developed before the new developments in steam compressors.

Several years ago the Westinghouse R&D Center in Pittsburgh was awarded a contract to develop a methanol heat pump. Methanol was chosen mainly because the specific volume is less than that of steam. The lower specific volume allows the use of a compressor smaller than that for low pressure steam.

The first phase of the two phase program was development, design, fabrication, and laboratory testing of a prototype. The second phase is demonstration in an industrial users plant. The heat pump was designed for upgrading of 10 psig steam from a TMP plant which was to have been built by Crown Zellerbach.

Phase 1 is now complete and the unit has been tested. The test site is outdoors to reduce the explosion and fire risks. The atmospheric boiling point of methanol is 65.5 C (150) F. To allow for temperature differential required for heat transfer, and the fact that the evaporator pressure is determined by the source leaving temperature, the source temperature must be 82 C (180 F) plus.

A vacuum in the system could lead to an explosion. To avoid that, methanol is automatically recycled to maintain temperature in the event of loss of source. The electrical input to the motor maintains temperature. A second line of defense is a nitrogen system to ensure that if a vacuum does develop, air will be excluded.

The fact that methanol is both explosive and toxic does introduce some risk.

The risk is probably manageable but is a disadvantage. It can be avoided by using a steam compressor or a steam generating freon heat pump/steam compressor combination. Crown zellerbach did not go ahead with the TMP plant. Finding an industrial demonstration opportunity has been difficult but Abitibi Price may be interested in the methanol heat pump.

In discussing the compressor selection, Mssrs. W. C. Moreland and R. W. Wolfe of Westinghouse commented in a technical presentation as follows: "It was found that the cost of the standard heavy duty chemical industry centrifugal compressor was such that, when designed into a heat pump system, they jeopardize its economic viability. We were fortunate, in finding, however, a small manufacturer with a unique high tip speed design. This unit is very compatible with the compression of methanol which is a high head fluid which requires a high impeller tip speed. They build five frame sizes with an integral gear box and in addition, for applications requiring two stages they build a compact unit wherein two compressors are driven from a single gear box."

The small manufacturer they refer to is Atlas Copco Turbinetics. According to Moreland, the project engineer, the price of the Atlas Copco Turbinetics compressor was roughly half that quoted by the longer established suppliers with their heavy duty designs. It was the high cost of those heavy duty designs in the large sizes required for low pressure steam which pointed the way to the methanol heat pump development at the outset.

The unique high tip speed design of the Atlas Copco Turbinetics compressor makes it ideal for compression of low pressure steam. As compressor size increases, the cost increase is surprisingly small. Thus, the low specific volume of atmospheric or sub atmospheric steam is not a major disadvantage. Following are estimating prices for Atlas Copco Turbinetics compressor units without motors:

SC 6 $160,000
SC 10 $170,000
SC 14 $182,000
SC 20 $198,000
SC 28 $202,000

The SC 6 handles about 1000 ACFM (actual CFM) of steam. The SC 28 unit will compress 30,000 ACFM of steam. The specific volume of 10 psig steam is 16.3 cubic feet/lb.

Thus the SC 28 unit will upgrade 110,000 lbs per hour of 10 psig steam to 35 psig. This demonstrates that using a high temperature refrigerant such as methanol as an alternative to direct steam compression does not reduce the compressor cost very much. It argues for direct steam compression for source temperatures near the atmospheric boiling point of water.

R114 Steam Generating Heat Pump

Refrigerant R114 is firmly established for ind trial source temperatures below the atmospheric boiling point of water. It is a non toxic, non combustible flourocarbon. R114 is widely used as a working fluid for industrial heat pumps.

The atmospheric boiling point of R114 is 3.8 C (38.8 F). Thus there is no risk of vacuum at industrial process temperatures.

Fig. 1 shows thermal degradation of pure R114 vs temperature. The saturation temperature of 10 psig steam is 115 C.(240 F). Assuming a 10 degree F temperature differential between the condensing freon and the evaporating water, the freon temperature will be roughly 121 C (250 F). At that temperature level, thermal degradation of pure R114 is acceptable (1% per year) with carbon steel and negligible with stainless steel. The presences of oil accelerates the rate of thermal degradation slightly. By using appropriate synthetic oils, it can be kept within acceptable limits. Oil flooded screw compressors are widely use in refrigeration systems. As well, sealing systems of some centrifugal compressors introduce oil to the refrigerant.

Mycom, a Japanese manufacturer and Stal Refrigeration of Sweden have operated oil flooded screw compressors with R114 at temperatures high enough for steam generation. This and other evidence indicates that oil flooded screw compressors should be satisfactory for low pressure steam generation.

Somewhat higher steam pressures can be generated by using a centrifugal compressor with a seal which does not add oil to the refrigerant.

At 121 C (250 F) the latent heat of vaporization of R114 is 30.47 BTU per pound. The specific volume is 0.09 cubic feet per pound.

The saturation pressure of R114 at 250 F is 290 psig. Thus the latent heat of vaporization is adequate and the pressure is easily manageable.

An Atlas Copco turbinetics single stage steam compressor can upgrade 10 psig steam to 35 psig. That pressure is adequate for newsprint drying in most cases. Staged feedwater heating (not to be confused with heating feedwater makeup) with 35 psig steam is the best way to use the waste heat in many cases.

Where higher steam pressures are required, screw type steam compressors may be the best solution. A single stage unit of this type can deliver steam at at least 110 psig if the supply is 10 psig steam. If the supply is 5 psig, steam at at least 85 psig can be delivered. If a steam generating R114 heat pump generated steam at 1 psig, that could be upgraded to 65 psig or more using a single stage screw type steam compressor.

Clearly when a heat pump capable of generating steam at just above the atmospheric boiling point of water becomes available, the full range of source temperatures of interest in industry will be covered in meeting process steam requirements.

One alternative is a binary R114/methanol approach. For a source below the lower limit for methanol (roughly 180F), R114 would absorb heat from the source. The R114 would be compressed and condensed in a heat exchanger boiling methanol. The methanol would be compressed and condensed in a heat exchanger generating steam. This is technically feasible providing demonstration proves methanol to be a satisfactory working medium. Methanol can be used to generate steam at 60 psig or more.

The disadvantage of this binary approach is that three heat exchangers are required. The methanol compressor may be slightly less expensive than the corresponding steam compressor. The R114/steam compressor combination, however requires only two heat exchangers. The heat exchangers are the most costly components of a heat pump system. There is not enough difference in compressor price to justify dealing with a toxic, inflammable, explosive working medium plus additional heat exchange surface.

If methanol fits into the scheme of things at all, it would appear to be for sources from 82 C (180F) to just above the atmospheric boiling point.

Pulp refiners operating at atmospheric pressure are an interesting case. Steam is available as a source but is difficult to capture it without significant air contamination. The air impedes heat transfer. The steam is contaminated and must be used in a reboiler or heat pump to produce clean steam.

Flakt have an order for a system consisting of a reboiler to produce clean steam at slightly less than atmospheric pressure. The clean steam will be compressed with a screw type steam compressor to supply newsprint dryers. The disadvantage of this is that any leakage into the clean steam side of the reboiler would cause air contamination of the steam for the paper dryers. Air in paper dryers can cause serious problems.

A methanol heat pump could be used instead of the reboiler/steam compressor combination. That would eliminate the risk of air contamination of the steam.

A further alternative is to compress the contaminated steam, and supply it to the reboiler. The clean steam would then be generated under positive pressure. A good cyclone separator and a scrubber would be required before the compressor but the compressors can handle contaminated vapour. All this assumes that the contaminated steam can be captured with very little air in it. An easier approach for atmospheric refiner systems where it is difficult or impossible to capture the steam without much air in it is to use the steam to heat water. The water would then serve as a source for an R114/-steam compressor combination. One of many arguments for developing the steam generating R114 heat pump.

## Swedish Industrial Heat Pump Developments

Atlas Copco, a firm with many years of compressor background, is strong in open cycle heat pumps. They manufacture screw steam compressors in Belgium and centrifugal compressors in Albany N.Y. (Atlas Copco Turbinetics). There will be a small screw compressor in the U. of Ottawa. The atmospheric refiner installation in a Swedish pulp and paper mill discussed above is probably the most interesting application.

There are many Atlas Copco Turbinetics centrifugal compressor installations. A vapour compression evaporation application at Canada Starch in Cardinal, Ontario is an example. Another is a TMP heat recovery application in a Publishers paper Mill in Oregon City, Oregon.

ASEA, a very large, highly competent Swedish firm controls three companies involved in industrial heat pumps. They own Flakt, a major, highly regarded supplier of energy systems to the Canadian Pulp and Paper Industry (and the Pulp and Paper Industry world wide); Stal Laval, a leading supplier of industrial steam turbines and Stal Refrigeration, a supplier of industrial refrigeration systems and manufacturer of oil flooded screw type refrigeration compressors.

Stal Laval now has 80 people working on large heat pumps. The bulk of the current effort is directed towards 10 MW and up units for district heating systems. In most cases the source is treated sewage water. They have been highly successful.

Stal Laval used Sulzer compressors for the first units. They have recently developed their own compressors. In all cases they use centrifugal compressors. Stal Laval is a leading supplier of high speed gears. They use constant speed motors with geared drives. They can shift gears to change compressor speed range. Vanes are used as the basic control but the gears enable the compressors to handle a much wider range.

Stal Laval are planning to develop a steam generating R114 heat pump for sources in the temperature range from 55 C (130 F) to about the boiling point of water. They will use steam compressors to reach steam pressures suitable for industrial processes. There are two engineers working full time on the industrial heat pump development.

Industrial heat pump development has been accorded high priority in the medium term. The short term concentration is on district heating because the company has a great many orders for these units. When the demand in Sweden is satisfied, they will sell to district heating systems elsewhere in Europe.

The first Stal Laval steam generating heat pump will be in a Swedish pulp and paper mill near the Stal Laval headquarters. They are assuming that oil from the compressor seals will contaminate the R114 and are taking this into account in limiting the steam pressure/temperature. The advertising literature indicates a steam temperature of 105 C (221 F). That corresponds with a pressure of about 20.68 kPa or 3 psig.

They will use either a two stage centrifugal compressor or a screw compressor to produce steam for paper drying. Stal Laval will not produce steam compressors. Atlas Copco is affiliated with ASEA so the are inclined to use Atlas Copco steam compressors but that is not a firm rule.

G. A. Robb discussed the Stal Laval industrial heat pump plans at length with Lars Ljung who is responsible for the program. They are thoroughly engineering 2 sizes before going ahead with development and demonstration. One is a 5 MWT shop assembled module and the other an 18 MWT field assembled system.

The 5 MWT (17 MBTU/hr or 18 GJ/hr) shop assembled system will be built on a flat bed truck platform in a prefabricated building. The trailer will be moved to the site where the tractor and chassis will be removed. This eliminates the need for a crane and allows shop assembly of the entire system. It should be noted that the 5 MWT applies to the output of the R114 steam generating heat pump/steam compressor combination. Most of the electrical input to the steam compressor appears as heat in the steam.

The 18 MWT (61 MBTU or 65 GJ) system would remove 12.5 MWT (42.6 MBTU/hr or 45 GJ) from the source, require 3.5 MWE to drive the heat pump and 2 MWE to drive the steam compressor. Steam at 4 atmospheres (45 psig or 310 kPa) would be produced. The cost is estimated to be $4.3 million for the steam generating heat pump/steam compressor system. The COP will be 2.9. The source would be water at 50 C (140 F).

Stal Refrigeration was recently acquired by ASEA from Alpha Laval and is now helping Stal Laval. Stal Refrigeration has sold a good many heat pumps to various industries. They have a number of R114 installations, some operating above 100 C.

PROFITABILITY - BENEFITS & COSTS OF STEAM GENERATING R114 HEAT PUMPS IN THE PULP AND PAPER INDUSTRY

The coefficient of performance of will be tend to be on the low side (2.5 to 3.5) compared with most water heating applications. Thus if the drive is electric, more electricity will be required. The impact of the electrical requirement on profitability depends on the relationship between the cost of electricity and the cost of the displaced fuel.

It is important to bear in mind that one GJ of thermal energy from the heat pump will displace about 1.22 GJ of fuel. Industrial boiler efficiencies with fossil fuel are roughly 85%. If steam plant losses and uses amount to 3%, the efficiency of conversion from fuel heat to steam heat is 82%. This is a reasonable estimate although there are variations among pulp and paper mills.

**Electricity Rates**

Most Canadian utilities use Hopkinson 2 part rates. A demand charge roughly covers capacity costs which are fixed. An energy charge roughly covers the variable cost which is mainly fuel in a thermal system.

Quebec and British Columbia are, essentially all hydro systems. Each has a single fossil thermal plant but these are rarely used. About one third of the electrical energy produced in Ontario is from hydro, one third from nuclear plants and one third from conventional thermal plants (almost entirely coal).

About half of Nova Scotia's electrical energy is from coal, 35% is from oil and 15% is from hydro sources. Electrical rates in Nova Scotia are higher than in other major pulp and paper producing provinces. During the 1960's the province, with Federal encouragement, became largely dependent on oil for electrical generation. The current policy is to build new coal fired generation and use oil only for peaking. This has left Nova Scotia with a lot of unused, relatively new oil fired capacity. The carrying cost of this unused capacity, together with a large fraction of capacity built at the inflated costs of recent years, leaves Nova Scotia with high capacity costs. Electrical energy costs are high because of the dependence on fossil fuels.

Most of the potential is in Quebec, Ontario and British Columbia where electrical rates are relatively low.

The Quebec Policy is to keep industrial electrical rates about 10% below those in Ontario. The average cost of electrical energy to large industrial users in Ontario is about 2.6 cents per kwh. About 1.7 cents per kwh is the energy charge. In British Columbia the average cost at 90% load factor is about 2.2 cents per kwh. Of that, 1.63 cents is the energy charge. In Nova Scotia the unsubsidized average at 90% LF is 4.68 cents/kwh of which 3.7 cents/kwh is the energy charge.

Electrical rates in New Brunswick, an important pulp and paper province, are less than those in Nova Scotia but substantially higher than in Ontario, B. C. or Quebec. The cost to large industrials is 3.38 cents per kwh at 90% load factor. The energy charge is 2.35 cents. The Lepreau nuclear plant together with imports from Quebec and some in province hydro have enabled New Brunswick to keep electrical rates below Nova Scotia levels.

There are three major mills in Newfoundland. In two cases the mill owns a hydro plant. Each mill must be considered separately.

A heat pump installed in an existing pulp and paper mill to displace fossil fuel need not contribute to the peak electrical load. If the heat pump is shut down for the short periods of peak load on which the capacity charge is based, only the energy charge need be considered in determining the operating cost.

Modern demand control equipment monitors kw demand and calculates the rate of change in demand. If the controller forecasts that a new monthly peak will be established unless some load is shed, it will call for load shedding before a new peak is established.

If the heat pump is shut down for short periods, the fossil fuel boilers take over the steam load. A steam accumulator is an alternative energy storage device.

If the heat pump is not shut down to avoid establishing new monthly peaks, then it contributes to the peaks and the average cost should be used in the profitability analysis.

**Cogeneration Effect**

In some regions some pulp and paper mills generate electricty as a byproduct of process steam. High pressure steam passes through non condensing steam turbine generators and is condensed in paper dryers or pulp digesters.

The latent is used - not lost to river water or a cooling tower as in a single purpose steam electric station. This is by product power generation or "cogeneration" and requires less than half the fuel per kwh.

A heat pump reduces cogeneration potential. A modern cogeneration system using 6205 kPa (900 PSIG) steam can generate about 70 kwh of electrical energy per MBTU (1.055 GJ) of process heat if the noncondensing turbine exhausts to the process at 379 kPa (55 psig),A heat pump/ steam compressor combination with an output of 17 GJ/hr (16.1 MBTU/hr) would reduce the electrical output of a cogeneration system by about 1127 kw.

The cogeneration heat rate in terms of steam heat is about 3800 GJ/kwh (3600 BTU/kwh). If the oil cost is $30/bbl, the fuel heat cost would be about 30/6.3 = $4.76/MBTU ($4.51/GJ). The steam heat cost would be 4.76/.82 = $5.80/MBTU or $5.50 per GJ. The fuel component of the cost of cogenerated electricity would be (3800 x $5.50)/1,000,000 = 2.09 cents per kwh.

In Nova Scotia, the average cost per kwh as approved by the Public Utilities Commission is about 4.6 cents per kwh at 95% load factor. The government pays a subsidy of about 9% but there is pressure to remove the subsidy. At the subsidized price of about 4 cents per kwh, the difference in cost between cogenerated electricity and purchased electricity would be 4 - 2.09 = 1.91 cents per kwh. The cogeneration effect would amount to .0191 x 1127 x 8000 = $172,206 per year, assuming 8,000 operating hours per year.

The cogeneration effect is very important in the Nova Scotia case illustrated. There are three major pulp and paper mills in Nova Scotia and two of them have modern 900 psig cogeneration systems.

Many of the mills in British Columbia cogenerate. Some use 900 psig but most use a steam pressure of 600 psig. The cost of electricity is considerably lower than in Nova Scotia. The average price to large industrials using the standard rate is about 2.3 cents per kwh. The above analysis applied to B. C. would result in a cogeneration effect of (.023 - .0209)x1127x8000 = $18,900 per year.

**Incentives**

The FIRE program provides grants of up to 20% for biomass energy systems. Heat recovery systems including heat pumps using fully demonstrated technology do not qualify for grants under any program. Heat pumps do qualify for a two year write off (50% straight line CCA) and an investment tax credit but not a grant. Class 34 was established specifically to provide a 50% straight line capital cost allowance for cogeneration systems, heat recovery systems etc. (according to a recent amendment only 50% of the capital cost is eligible the first year so the capital cost allowance is 25% of the total capital cost the first year, 50% the second and 25% the third year). This incentive is also available for wood residue boilers etc. ie it is also available to the other routes to oil displacement.

Manufacturing and processing equipment gets the same tax treatment under class 29 as energy conservation equipment under class 34. There are no incentives to chose heat pump investments (unless they qualify as demonstrations) in preference to other pulp and paper equipment investments involving fully proven and demonstrated technology. There are incentives for demonstrations.

**Measures of Profitability**

Pulp and Paper companies use a variety of measures of profitability in selecting projects. Internal Rate of Return, interest coverage impact and impact on return on common equity are among the best. For projects of this size, payback and internal rate of return are the most likely to be used by the Pulp and Paper companies. Consideration of interest coverages and return on common equity require the preparation of forecast or proforma financial statements. This can be done fairly quickly with financial models and computer programs. It is justified if relatively large investments are being considered.

The common equity ratios of most companies are currently too low. There is too much debt in the capital structure, in most cases. Unless the company is willing to sell more common equity, there is in most cases a fixed amount of money available for capital investment. The heat pump project must compete with investments to reduce wood costs (wood is the largest single expense), labour costs etc. and quality improvements. As well, there are other potential energy investments including those eligible for FIRE grants or gas conversion grants.

The After Tax Internal Rate of Return is the discount rate which will equate the net present value of the net incremental cash flow after tax to the capital cost. After the first few years which are complicated by capital cost allowances etc., the net incremental cash flow is equal to the after tax net income increase attributable to the project.

The Internal Rate of Return is sometimes called the discounted cash flow rate of return. It takes account of the time value of money. Dollars received in the early years are worth more because they can be invested to earn interest or another form of return. Because it considers only cash flows, it does not involve arbitrary estimates of depreciation etc.

The internal rate of return is the effective yield of the investments. It can be compared with the rate of return or yield on alternative investments in terms of opportunity cost.(Samuelson notes that "if Robinson Crusoe were to pick raspberries, the cost of the raspberries can be thought of as the sacrificed strawberries he might have picked with the same effort").

A hurdle rate of return is generally established. Projects with IRR's higher than this are kept in the capital budget and may or may not be approved.

The payback method of ranking investment alternatives appeals to business executives. It is considered misleading by many academics because it does not consider the time value of money and could lead to the wrong choice in long run terms.

The before tax payback period is the simplest rough test. It is the time required for the operating savings to equal the original cash outlay. As soon as an engineer has determined the the annual savings and estimated the capital cost he can quickly calculate the before tax payback. A more meaningful test is the after tax payback. This is the time required for the expected after tax cash inflows to equal the initial cost. Capital cost allowances and investment tax credits have a large impact in the first three or four years. After that the after tax net incremental cash inflow may be perhaps 55% of

the operating savings. For the first three or four years, before and after tax cash flows will be much more nearly equal providing the company is in a position to take advantage of CCA. This is illustrated in the computer printouts in Appendix A.

Executives of large public companies must consider the short term impact on financial ratios and financial statements. If these are not as they should be, the executives may not be reappointed. The capital markets will react. A company with poor financial ratios will pay higher interest on borrowings and have more difficulty attracting equity capital. Private companies whose financial statements are not published are in a better position to consider the long term.

The hurdle IRR for a particular company at a point in time will depend on anticipated interest rates and on returns on alternative investment opportunities. Risk must also be considered.

Currently the Bank of Canada rate is just over 10%, the bank prime rate is 11% and 5 year mortgage rates are in the 12 to 13.5% range. These are indications of the potential return on investments with little or no risk.

Projects using the steam generating R114 heat pump proposed here must generate IRR's well in excess of these basic rates. **The analysis reveals that rates of return for 2 16 GJ/hr (15MBTU/hr) with a single steam compressor would be significantly higher than a single 16GJ/hr heat pump with a steam compressor. A two heat pump single compressor scheme would have an IRR of roughly 30% in Ontario, Quebec or B. C.** (see appendix A page 22.)

A three heat pump single compressor scheme would be more profitable than the 2 heat pump scheme. The advantage of using 2 or three 16GJ/hr heat pumps is that they can be staged to improve the COP. This is illustrated in fig. 1 as applied to a stone groundwood mill in a newsprint mill. This scheme is applicable to a great many Canadian newsprint mills.

The hurdle rate will likely be roughly 15%. It is safe to assume that most years a heat pump project must compete with rates well above

that. Projects with an IRR of 18% should be competitive. In terms of payback, 3 years is a popular target now. If year 1 is considered to be required to put the project into operation, almost all the cash flow that year will be CCA and investment tax credit. Many analysts call this year 0 although in this report it is considered year 1. The 3 years would be years 2,3 and 4. The sum of the cash flows in those 3 years should equal the initial cost if the payback is 3 years.

A review of Appendix A indicates that using fuel prices and electrical rates for Quebec, Ontario and B. C. the hurdle rate is exceeded.

**Boiler fuel prices**

Steam from heat pumps must compete with steam from natural gas, heavy fuel oil, coal and wood residues.

Great Lakes Paper at Thunder Bay, James River, Canada Ltd.at Marathon, Ontario, the Abitibi mill at Pine Falls and the Boise Cascade mill at Kenora all use coal. Coal accounts for a small fraction of the boiler fuel used by the pulp and paper industry.

Pine Falls and Kenora use Saskatchewan Lignite. Great lakes and Marathon use U. S. bituminous coal. The cost of steam from coal is substantially less than the cost of steam heat from heavy fuel oil or natural gas. While there are large differences in the delivered cost among mills, it is reasonable to think in terms of steam costs as low as $3.50/GJ with coal.

Extension of natural gas systems is making that fuel available to most pulp and paper mills in British Columbia, Ontario and Quebec. Heavy fuel oil will remain the basic fossil boiler fuel on Vancouver Island unless a natural gas pipeline is built.

In the great majority of cases, steam from natural gas will be the fuel displaced by steam from heat pumps. The detailed sensitivity analysis in Appendix A shows cash flows and rates of return based on a wide range of fuel prices. Each set of calculations is based on an assumption as to steam heat cost. The corresponding fuel oil and natural gas prices appear near the bottom of the page. A natural gas cost of about $4.50/GJ is reasonable in the east. Mills in the B. C. interior pay less but the difference is decreasing.

## THE MARKET FOR A HEAT PUMP TO GENERATE STEAM WITH SOURCES FROM 55 DEGREES C TO THE BOILING POINT OF WATER

G. A. Robb Associates recently completed a study of the potential for heat pumps in the Canadian Newsprint Industry. That study, funded by the Canadian Electrical Association, led to the conclusion that heat sources at temperatures above 55 C should be used to generate process steam. Lower temperature heat should be upgraded to serve the lower temperature requirements now met by degrading the higher temperature sources.

The Pulp and Paper Industry uses as three times as much oil and as much natural gas as any other Canadian Industry. Very large quantities of air and water, used by pulp and paper processes, become effluents at temperatures far above ambient levels.

Heat recovery using heat exchangers has been important in the industry for many decades. Higher temperature sources are used to meet lower temperature requirements.

The lower temperature effluents are rejected to rivers or to the atmosphere. If heat pump systems generating process steam are used to upgrade the higher temperature sources, the lower temperature requirements can be met by heat pumps upgrading lower temperature effluent heat.

A typical newsprint mill uses roughly 20,000 US gallons or 78,000 litres per tonne of product. A representative effluent temperature is 21 C or 70 F in winter. The effluent flow from a 500 tonne per day mill would be roughly 3,722,222 lbs per hour. The temperature of that flow could be reduced 20 F ( a source leaving temperature of 50 F), to produce 130 F (54 C) water. The output of the heat pump would be 97 MBTU (102 GJ) per hour or 31 MWT. According to Templifier literature the COP 3.9. (thermal output divided by thermal equivalent of electrical input = 3.9)

The 54 C water can be used for air and water preheating. This is essential to counter the argument that upgrading higher temperature heat sources to produce process steam, will lead to an equivalent increase in fuel requirements for preheating air and water.

In a newsprint mill, electrical energy drives grindstones or refiner disks used to separate the fibres. Most of the electrical input to the motors appears as heat in steam (140C), pulp (82C) or white water (68C) .

In the early decades of the industry, newsprint was made from a blend of about 75% stone groundwood pulp and 25% long fibre chemical pulp. The stone groundwood process yields almost one tonne of pulp per tonne of wood. Chemical pulping yields only about half a tonne of pulp per tonne of wood. Over the years, the aim has been to reduce the chemical pulp fraction.

New newsprint mills use nearly 100% thermomechanical pulp made with refiners. The chips are presteamed and one or 2 stages of refiners are pressurized with steam. Between the traditional 25% chemical pulp/75% stone groundwood approach and 100% TMP, are an endless variety of refiner pulps preceded by varying amounts of chemical pretreatment blended with varying percentages of stone groundwood. These systems allow some stone groundwood to be used without chemical pulp.

Heat from stone groundwood pulp or groundwood white water is the largest potential source in the range most suitable for process steam generating heat pumps. It can be captured at temperatures between 65 C (150 F) & 82 C (180 F).

Other sources in this range are white water from either pressurized or atmospheric refiners. The steam/air mixture from atmospheric refiners can be used to heat water to temperatures in this range. The water can then serve as a heat pump source.

Another very large potential source is heat rejected by the air/vapour mixture from paper machine dryers. This can be used to heat water to 54.4 C (130 F) in the case of a specially designed hood (enclosure) and recovery system. It is standard practice to heat water to 49 C (120 F) with modern paper machine hoods and heat recovery systems. This is a most interesting source because the dryer section is also the main user. The temperature is at the low end of the range of economic interest. Low electricity prices would be required.

A further reason for serious consideration of the the paper machine dryer exhaust as a source is the fact that it is available in any paper mill. Mills using recycled paper or purchased pulp (mills making fine papers such as bond for example) do not have pulping system heat sources.

Bleached kraft pulp mills account for about 7 million annual metric tonnes of production in a representative year. They rank second to newsprint mills which produce about 9 million tonnes per year. These two products account for about 76% of total annual Canadian production of some 21 million tonnes. The other 5 million tonnes is a mix of liner board, fine paper (eg. bonds), corrugating medium, bag papers etc.

Bleached kraft market pulp mills as a group use a lot of oil. Nevertheless heat pumps will play a less important role than they will in newsprint, because a bleached kraft market pulp mill can derive all energy requirements except for lime kiln fuel from biomass. At least three Canadian mills achieve this.

The older kraft mills will find heat pumps a less expensive route to energy conservation than process modifications in some cases. A number have installed scrubbers to reduce black liquor recovery boiler emissions. These produce large flows of hot water at 71 C (160 F)- a good heat pump source.

Bleached kraft market pulp mills use a great deal of steam heat - far more than their fossil fuel consumption would indicate. More than half is generated by burning the organic material removed from the wood in the cooking process. As well, two tonnes of wood are required per tonne of pulp produced so there is far more bark to burn. The very large steam flows make staged feedwater heating a logical heat pump application. Water from the recovery boiler scrubber, condenser water from multiple effect evaporators and water heated with pulp dryer exhaust streams are among the potential sources.

Unlike newsprint dryers which operate at low temperature/pressure levels and are ideal heat pump heat sinks; pulp dryers normally operate at about 160 psig - too high for heat pumps.

Recently, Flakt, a Swedish company which is by far the largest supplier of pulp dryers has designed pulp dryers to operate at low pressure. The aim is to allow mills to benefit more from cogeneration and heat pumps.

According to the G. A. Robb Associates study for the Canadian Electrical Association, the Canadian newsprint industry could use some 150 steam generating R114 heat pumps, some with steam compressors and some without. That study is to be updated and expanded to deal with the entire Canadian Pulp and Paper Industry, the Chemical Industry and the Food and Beverage Industry.

Preliminary work leading up to the second study suggest the market for heat pumps in the newsprint industry is probably greater than the first study indicated. As well, the market in other types of Pulp and Paper and in other industries is substantial.

Drying newsprint almost certainly uses more fossil fuel than does any other single process in Canadian Industry. Most newsprint machine dryer sections use steam in the 124 kPa (15 psig) to 172 kPa (25 psig) range. Canada produces some 9 million tonnes of newsprint per year. The drying steam requirement per tonne is roughly 3 million BTU or 3.16 GJ. Thus at least 28 million GJ of steam heat is required. That would require some 218 steam generating heat pump/steam compressor combinations rated at 16 GJ each. Additional heat pumps can be used for staged feedwater heating in the Canadian newsprint industry.

Staged feedwater heating is another very important potential use for the steam generating R114 heat pump. The makeup can be heated using currently available R114 heat pumps designed to heat water directly. The mixture of makeup and condensate normally goes to a deaerating feedwater heater.The deaerator is an open tank into which steam is introduced to bring the water to the boiling point to drive off noncondensible gases. This steam can be provided by an R114 steam generating heat pump or a heat pump/ compressor combination, depending on the deareator pressure. Additional stages of feedwater heating, using closed feedwater heaters supplied by a heat pump/steam compressor, can also be provided.

Staged feedwater heating makes sense in any industrial steam plant with a suitable source and an appropriate electrical rate/ fuel price relationship.

The reason there is so much absorptive capacity for heat in boiler feedwater systems, is the fact that the steam is generated at temperature pressure levels far above process level. As lower pressure steam from heat pumps or TMP is substituted, the absorptive capacity of the feedwater systems will decline. In cases where process temperature levels are too high to be economically met with heat pumps, staged feedwater heating will remain a very important application of heat pumps.

Because newsprint represents the largest market for steam generating heat pumps, it is important to consider the impact of thermo-mechanical pulping (TMP). With TMP, that fraction of the heat from the electric motors which appears as steam, can be converted into clean steam for newsprint drying without heat pumps. A substantial fraction, perhaps 30% remains in white water at about 71 C (160), a temperature suitable for the steam generating R114 heat pump. As well, many mills have elected to retain a good deal of stone groundwood capacity. While most new mills will be 100% TMP, there will be very few new mills.

It is because the newsprint industry cannot afford to abandon the very large investment in stone groundwood capacity, that it has developed techniques for replacing chemical pulp with chemi-mechanical pulps which allow retention of stone groundwood.

Demonstration of heat recovery from stone groundwood using steam generating R114 heat pumps should reduce the incentive to substitute TMP. As well, a fraction of the electrical energy from TMP refiner motors appears in white water at temperatures suitable for the R114 steam generating heat pump.

The air and water preheating (discussed at the beginning of this section) to make more intermediate temperature heat available for steam generation requires low temperature hot water or water glycol systems which would complement existing existing steam systems in some cases and replace them in others.

APPENDIX A

Summary of Heat Pump Project Profitability Data

| Project | Elect.* Cost | Steam* Heat Cost | Heavy* Oil Price | | 20 Year After Tax Int. Rate of Return |
|---|---|---|---|---|---|
| | $/KWh | $/MBTU | $/Bbl. | $/MBTU | ( %) |
| Port Alfred, | | | | | |
| Base Case | 0.017 | 6.0 | 31.00 | 4.92 | 27.3 |
| (Cap. Cost= | | 5.5 | 28.41 | 4.51 | 24.2 |
| $1,307,000) | | 5.0 | 25.83 | 4.10 | 21.0 |
| (Output= | 0.020 | 6.0 | 31.00 | 4.92 | 25.0 |
| 16.2 MBTU/hr) | | 5.5 | 28.41 | 4.51 | 21.7 |
| | | 5.0 | 25.83 | 4.10 | 18.1 |
| | 0.025 | 6.0 | 31.00 | 4.92 | 20.6 |
| | | 5.5 | 28.41 | 4.51 | 16.7 |
| | | 5.0 | 25.83 | 4.10 | 12.1 |
| As with Base Case but with 2 HP's | | | | | |
| & 1 St Comp. | 0.017 | 6.0 | 31.00 | 4.92 | 32.9 |
| (Cap. Cost= | | 5.0 | 25.83 | 4.10 | 25.7 |
| $2,100,000) | 0.020 | 6.0 | 31.00 | 4.92 | 30.3 |
| (Output= | | 5.0 | 25.83 | 4.10 | 22.6 |
| 32.4 MBTU/hr) | 0.025 | 6.0 | 31.00 | 4.92 | 25.5 |
| | | 5.0 | 25.83 | 4.10 | 16.2 |
| Gatineau | | | | | |
| Heat Pump | 0.020 | 6.0 | 31.00 | 4.92 | 31.5 |
| (Cap. Cost= | | 5.5 | 28.41 | 4.51 | 28.3 |
| $800,000 ) | | 5.25 | 27.12 | 4.31 | 27.12 |
| (Output= | | 4.72 | 24.38 | 3.87 | 22.5 |
| 15 MBTU/hr) | 0.017 | 6.0 | 31.00 | 4.92 | 34.0 |
| | | 5.5 | 28.41 | 4.51 | 28.3 |
| | | 4.72 | 24.38 | 3.87 | 25.0 |

*As of the beginning of year 2 assumed to be first full year of operation

Summary of Cost of Heat Pump OUTPUT COST - Various Assumptions

| Port Alfred Base Case Capital Cost | Cost of Elec. Input $/KWhe | Fixed Charge Rate | Variable Cost of Output $/KWht | Variable Cost of Output $/MBTU | Fixed Charges Output $/KWht | Total Cost Output $/KWht | Total Cost Output $/MBTU | Total Cost Output $/GJ |
|---|---|---|---|---|---|---|---|---|
| $1.387 million | .017 | .17 | .0062963 | 1.844798 | .0058513 | .0121476 | 3.559227 | 3.373675 |
| COP 2.7 | .02 | .17 | .0074074 | 2.170351 | .0058513 | .0132588 | 3.884788 | 3.682256 |
| 16.2 MBTU/hr out | .025 | .17 | .0092593 | 2.712939 | .0058513 | .0151106 | 4.427368 | 4.196557 |
| 17.1 GJ/hr out | .017 | .15 | .0062963 | 1.844798 | .0051638 | .0114592 | 3.357538 | 3.182493 |
| 4746.5572 KWt out | .02 | .15 | .0074074 | 2.170351 | .0051638 | .0125704 | 3.683982 | 3.491873 |
| 8000 hrs/year | .025 | .15 | .0092593 | 2.712939 | .0051638 | .0144222 | 4.225678 | 4.005374 |
| 37972458 KWht/yr | | | | | | | | |
| 129600 MBTU/yr | | | | | | | | |
| As with Base Case but with | | | | | | | | |
| 2 heat pumps and 1 steam | .017 | .17 | .0062963 | 1.844798 | .0047008 | .0109971 | 3.222113 | 3.054136 |
| compressor COP 2.7 | .02 | .17 | .0074074 | 2.170351 | .0047008 | .0121082 | 3.547666 | 3.362716 |
| 32.4 MBTU/hr = 34.2 GJ/hr | .025 | .17 | .0092593 | 2.712939 | .0047008 | .0139600 | 4.090253 | 3.877817 |
| 9493.114 KWt out | .017 | .15 | .0062963 | 1.844798 | .0041477 | .0104440 | 3.060876 | 2.900546 |
| 75944915 KWh/yr | .02 | .15 | .0074074 | 2.170351 | .0041477 | .0115552 | 3.385629 | 3.209127 |
| 259200 MBTU/yr | .025 | .15 | .0092593 | 2.712939 | .0041477 | .0134070 | 3.928216 | 3.723428 |
| Capital Cost $2.1 million | | | | | | | | |
| Gatineau Phase 2 | .017 | .17 | .0052632 | 1.542891 | .0038681 | .0091312 | 2.675425 | 2.535948 |
| Capital Cost $800,000 | .02 | .17 | .0061920 | 1.814225 | .0038681 | .0100600 | 2.947559 | 2.793894 |
| Output 15 MBTU/hr | .025 | .17 | .0077399 | 2.267781 | .0038681 | .0116080 | 3.401115 | 3.223806 |
| 4394.968 KWt | .017 | .15 | .0052632 | 1.542891 | .0034130 | .0086762 | 2.542891 | 2.409565 |
| 35159608 KWh/yr | .02 | .15 | .0061920 | 1.814225 | .0034130 | .0096050 | 2.814225 | 2.667512 |
| 120000 MBTU/yr COP 3.23 | .025 | .15 | .0077399 | 2.267781 | .0034130 | .0111529 | 3.267782 | 3.097423 |

Assuming maintenance cost of $25,000/yr cost/KWht = $.0006 which is negligible (.06 cents/KWht)

## EXPLANATION OF SENSITIVITY ANALYSIS OF PROFITABILITY

Pages 48 to 76 illustrate cash flows under various sets of assumptions. The measure of profitability is the after tax Internal Rate of Return (IRR). The IRR is the discount rate which equates the present value of net incremental cash flows to the capital cost. If the capital cost is considered as a negative cash flow, the IRR is the discount rate, which if applied to the cash flows of an investment, will yield a net present value of zero. This measure of profitability considers the time value of money. A dollar available today can be invested at some interest rate or rate of return so it has a present value greater than that of a dollar made available in a future year. The discount rate is the interest rate or rate of return at which it is assumed the future dollar could have been invested, had it been available today.

The tabulations also show before and after tax cash flows from which the after tax or before tax payback period can be determined. Payback periods are very important where there is substantial risk that the operation will be abandoned because it ceases to be profitable or for some other reason. If that happens cash flows for years well into the future will not materialize. Pulp and paper mills are very rarely abandoned because they are based on a renewable natural resource. Process changes may render a heat recovery system useless but that is unlikely. IRR is the most used method of selecting cost reduction projects.

The coefficients of performance are based on preliminary heat pump designs by potential suppliers. They are based on input KW, not shaft KW. The motor efficiency was assumed to be 90%. If a high efficiency motor is used, and it operates near full load most of the time, the efficiency may well be between 95% and 98%. This is offset by the fact that the assumption as to operating hours per year (8,000) may prove to be optimistic. Mill down time will depend on the market. Refiner downtime for plate changing and maintenance varies a good deal from year to year. Down time for heat pump system alterations and maintenance in the early years is decidedly uncertain. This is potentially far more significant than the actual maintenance cost.

There is uncertainty as to fuel cost and electrical rate escalation.

AFTER TAX All Cash Flows Thousands of $/year CDPA Fig 2

yr2 $/KWh .017 MBTU/hr output 16.2 000 hr/yr 0 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .242

yr 2 steam $/MBTU 5.5 Proj.cost 1317.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings $3 | 178.20 | 712.80 | 719.93 | 727.13 | 734.40 | 741.74 | 749.16 | 756.65 | 764.22 | 771.86 | 779.58 | 779.58 | 779. |
| Electrical cost | 59.57 | 238.27 | 252.57 | 267.72 | 283.79 | 300.81 | 318.86 | 337.99 | 358.27 | 379.77 | 402.56 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 118.63 | 469.53 | 462.11 | 453.89 | 444.82 | 434.85 | 423.92 | 411.96 | 398.91 | 384.70 | 369.27 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| Less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -177.69 | -123.12 | 165.78 | 453.89 | 444.82 | 434.85 | 423.92 | 411.96 | 398.91 | 384.70 | 369.27 | | |
| Less tax payable | -79.96 | -55.40 | 74.60 | 204.25 | 200.17 | 195.68 | 190.76 | 185.38 | 179.51 | 173.12 | 166.17 | | |
| Net Income | -97.73 | -67.72 | 91.18 | 249.64 | 244.65 | 239.17 | 233.15 | 226.58 | 219.40 | 211.59 | 203.10 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow $8 | 198.59 | 524.93 | 387.51 | 249.64 | 244.65 | 239.17 | 233.15 | 226.58 | 219.40 | 211.59 | 203.10 | 203.10 | 203. |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .223 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1186.10 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 28.41 | 28.70 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 | |
| " " " $/cuM | 178.80 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 | |
| " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 | |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 | |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 | |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 | |
| Average $per kwh | .017 | .01002 | .0191812 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 | |

AFTER TAX All Cash Flows Thousands of $/year CIPA Fig 2

yr2 $/KWh .017 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .235

yr 2 steam $/MBTU 5.5 Proj.cost 1317.00 x 1000 ku in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 58 | 178.20 | 712.80 | 719.93 | 727.13 | 734.40 | 741.74 | 749.16 | 756.65 | 764.22 | 771.86 | 779.58 | 779.58 |
| Electrical cost | 59.57 | 238.27 | 252.57 | 267.72 | 283.79 | 300.81 | 318.86 | 337.99 | 358.27 | 379.77 | 402.56 | |
| Maintenance cost | | 20.00 | 21.00 | 22.05 | 23.15 | 24.31 | 25.53 | 26.80 | 28.14 | 29.55 | 31.03 | |
| Operating savings | 118.63 | 454.53 | 446.36 | 437.35 | 427.46 | 416.62 | 404.77 | 391.86 | 377.80 | 362.54 | 346.00 | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | |
| less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Taxable income | -177.69 | -138.12 | 150.03 | 437.35 | 427.46 | 416.62 | 404.77 | 391.86 | 377.80 | 362.54 | 346.00 | |
| less tax payable | -79.96 | -62.15 | 67.52 | 196.81 | 192.36 | 187.48 | 182.15 | 176.34 | 170.01 | 163.14 | 155.70 | |
| Net Income | -97.73 | -75.97 | 82.52 | 240.55 | 235.10 | 229.14 | 222.62 | 215.52 | 207.79 | 199.40 | 190.30 | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Inv tax credit | 0.00 | | | | | | | | | | | |
| Net inc cash flow 30 | 198.59 | 516.68 | 378.84 | 240.55 | 235.10 | 229.14 | 222.62 | 215.52 | 207.79 | 199.40 | 190.30 | 190.30 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .215 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1184.20 (to year 11

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 28.41 | 28.70 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 |
| " " " $/cuM | 178.80 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 |
| " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 |
| Average $per kwh | .017 | .01882 | .0191812 | .0202473 | .0214421 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 |

AFTER TAX All Cash Flows Thousands of $/year CDPA Fig 2

yr2 $/KWh .017 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .225

yr 2 steam $/MBTU 5.5 Proj.cost 1367.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.789222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 58 | 178.20 | 712.80 | 719.93 | 727.13 | 734.40 | 741.74 | 749.16 | 756.65 | 764.22 | 771.86 | 779.58 | 779.58 |
| Electrical cost | 59.57 | 238.27 | 252.57 | 267.72 | 283.79 | 300.81 | 318.86 | 337.99 | 358.27 | 379.77 | 402.56 | |
| Maintenance cost | | 20.00 | 21.00 | 22.05 | 23.15 | 24.31 | 25.53 | 26.80 | 28.14 | 29.55 | 31.03 | |
| Operating savings | 118.63 | 454.53 | 446.36 | 437.35 | 427.46 | 416.62 | 404.77 | 391.86 | 377.80 | 362.54 | 346.00 | |
| Inv tax credit 10% | 136.70 | | | | | | | | | | | |
| Deemed Cap. cost | 1230.30 | | | | | | | | | | | |
| less CCA | 307.50 | 615.15 | 307.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Taxable income | -188.94 | -160.62 | 138.78 | 437.35 | 427.46 | 416.62 | 404.77 | 391.86 | 377.80 | 362.54 | 346.00 | |
| less tax payable | -85.02 | -72.20 | 62.45 | 196.81 | 192.36 | 187.48 | 182.15 | 176.34 | 170.01 | 163.14 | 155.70 | |
| Net Income | -103.92 | -88.34 | 76.33 | 240.55 | 235.10 | 229.14 | 222.62 | 215.52 | 207.79 | 199.40 | 190.30 | |
| Add back CCA | 307.50 | 615.15 | 307.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Inv tax credit | 0.00 | | | | | | | | | | | |
| Net inc cash flow 30 | 203.66 | 526.81 | 383.91 | 240.55 | 235.10 | 229.14 | 222.62 | 215.52 | 207.79 | 199.40 | 190.30 | 190.30 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .205 (to year 11

Project Cost less ITC 1230.30 x 1000 After tax present value= 1235.69 (to year 1

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 28.41 | 28.70 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 | |
| " " " " $/cuM | 178.80 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 | |
| " " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 | |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 | |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 | |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 | |
| Average $per kwh | .017 | .01882 | .0191812 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 | |

AFTER TAX All Cash Flows Thousands of $/year CBPA Fig 2

yr2 $/KWh .017 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .22

yr 2 steam $/MBTU 5.5 Proj.cost 1417.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 58 | 178.20 | 712.80 | 719.93 | 727.13 | 734.40 | 741.74 | 749.16 | 756.65 | 764.22 | 771.86 | 779.58 | 779.58 |
| Electrical cost | 59.57 | 238.27 | 252.57 | 267.72 | 283.79 | 300.81 | 318.86 | 337.99 | 358.27 | 379.77 | 402.56 | |
| Maintenance cost | | 20.00 | 21.00 | 22.05 | 23.15 | 24.31 | 25.53 | 26.80 | 28.14 | 29.55 | 31.03 | |
| Operating savings | 118.63 | 454.53 | 446.36 | 437.35 | 427.46 | 416.62 | 404.77 | 391.86 | 377.80 | 362.54 | 346.00 | |
| Inv tax credit 10% | 141.70 | | | | | | | | | | | |
| Deemed Cap. cost | 1275.30 | | | | | | | | | | | |
| less CCA | 318.83 | 637.65 | 318.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Taxable income | -200.19 | -183.12 | 127.53 | 437.35 | 427.46 | 416.62 | 404.77 | 391.86 | 377.80 | 362.54 | 346.00 | |
| less tax payable | -90.09 | -82.40 | 57.39 | 196.81 | 192.36 | 187.48 | 182.15 | 176.34 | 170.01 | 163.14 | 155.70 | |
| Net Income | -110.11 | -100.72 | 70.14 | 240.55 | 235.10 | 229.14 | 222.62 | 215.52 | 207.79 | 199.40 | 190.30 | |
| Add back CCA | 318.83 | 637.65 | 318.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Inv tax credit | 0.00 | | | | | | | | | | | |
| Net inc cash flow 30 | 208.72 | 536.93 | 388.97 | 240.55 | 235.10 | 229.14 | 222.62 | 215.52 | 207.79 | 199.40 | 190.30 | 190.30 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .198 (to year 11)

Project Cost less ITC 1275.30 x 1000 After tax present value= 1277.50 (to year 1

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 28.41 | 28.70 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 | |
| " " " $/cuM | 178.80 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 | |
| " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 | |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 | |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 | |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 | |
| Average $per kwh | .017 | .01882 | .0191012 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 | |

AFTER TAX All Cash Flows Thousands of $/year CSPA Fig 2

yr2 $/kWh .017 MBTU/hr output 16.2 888 hr/yr 7 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .215

yr 2 steam $/MBTU 5.5 Proj.cost 1317.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.789222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 13 | 155.93 | 623.70 | 629.94 | 636.24 | 642.60 | 649.02 | 655.51 | 662.07 | 668.69 | 675.38 | 682.13 | 682.13 |
| Electrical cost | 52.12 | 208.49 | 221.00 | 234.26 | 248.31 | 263.21 | 279.00 | 295.74 | 313.49 | 332.30 | 352.24 | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | |
| Operating savings | 103.81 | 410.21 | 403.69 | 396.47 | 388.50 | 379.74 | 370.13 | 359.63 | 348.17 | 335.69 | 322.14 | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | |
| Less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Taxable income | -192.52 | -182.44 | 107.36 | 396.47 | 388.50 | 379.74 | 370.13 | 359.63 | 348.17 | 335.69 | 322.14 | |
| less tax payable | -86.63 | -82.10 | 48.31 | 178.41 | 174.82 | 170.88 | 166.56 | 161.83 | 156.67 | 151.06 | 144.96 | |
| Net Income | -105.89 | -100.34 | 59.05 | 218.06 | 213.67 | 208.85 | 203.57 | 197.79 | 191.49 | 184.63 | 177.18 | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Inv tax credit | 0.00 | | | | | | | | | | | |
| Net inc cash flow 15 | 190.44 | 492.31 | 355.38 | 218.06 | 213.67 | 208.85 | 203.57 | 197.79 | 191.49 | 184.63 | 177.18 | 177.18 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .2 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1160.00 (to year 11

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 28.41 | 28.70 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 |
| " " " $/cuM | 178.00 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 |
| " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 |
| Average $per kwh | .017 | .01882 | .0191812 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 |

AFTER TAX All Cash Flows Thousands of $/year CSPA Fig 2

yr2 $/KWh .021 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .19

yr 2 steam $/MBTU 5.5 Proj.cost 1367.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.789222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 58 | 178.20 | 712.80 | 719.93 | 727.13 | 734.40 | 741.74 | 749.16 | 756.65 | 764.22 | 771.86 | 779.58 | 779.58 |
| Electrical cost | 73.50 | 294.34 | 312.00 | 330.72 | 350.56 | 371.59 | 393.89 | 417.52 | 442.57 | 469.13 | 497.27 | |
| Maintenance cost | | 20.00 | 21.00 | 22.05 | 23.15 | 24.31 | 25.53 | 26.80 | 28.14 | 29.55 | 31.03 | |
| Operating savings | 104.62 | 398.46 | 386.93 | 374.36 | 360.69 | 345.84 | 329.75 | 312.33 | 293.50 | 273.18 | 251.28 | |
| Inv tax credit 10% | 136.70 | | | | | | | | | | | |
| Deemed Cap. cost | 1230.30 | | | | | | | | | | | |
| less CCA | 307.50 | 615.15 | 307.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Taxable income | -202.96 | -216.69 | 79.36 | 374.36 | 360.69 | 345.84 | 329.75 | 312.33 | 293.50 | 273.10 | 251.20 | |
| less tax payable | -91.33 | -97.51 | 35.71 | 160.46 | 162.31 | 155.63 | 140.39 | 140.55 | 132.00 | 122.93 | 113.00 | |
| Net Income | -111.63 | -119.10 | 43.65 | 205.90 | 190.30 | 190.21 | 101.36 | 171.70 | 161.43 | 150.25 | 130.20 | |
| Add back CCA | 307.50 | 615.15 | 307.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Inv tax credit | 0.00 | | | | | | | | | | | |
| Net inc cash flow 30 | 195.95 | 495.97 | 351.22 | 205.90 | 190.30 | 190.21 | 101.36 | 171.70 | 161.43 | 150.25 | 130.20 | 130.20 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .17 (to year 11)

Project Cost less ITC 1230.30 x 1000 After tax present value= 1220.07 (to year 11

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .02

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 20.41 | 20.70 | 20.90 | 29.27 | 29.57 | 29.06 | 30.16 | 30.46 | 30.77 | 31.07 | |
| " " " $/cuM | 170.00 | 100.59 | 102.39 | 104.22 | 106.06 | 107.92 | 109.00 | 111.70 | 113.61 | 115.55 | |
| " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.04 | 4.00 | 4.93 | |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.50 | 4.63 | 4.60 | |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.70 | 5.04 | 5.90 | 5.96 | 6.02 | |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.40 | 5.53 | 5.59 | 5.65 | 5.70 | |
| Average $per kwh | .021 | .02226 | .0235956 | .0250113 | .0265120 | .0201027 | .0297009 | .0315762 | .0334700 | .0354791 | |

AFTER TAX All Cash Flows Thousands of $/year CSPA Fig 2

yr2 $/KWh .017 MBTU/hr output 16.2 000 hr/yr 4 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .24

yr 2 steam $/MBTU 5.5 Proj.cost 650.50 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 89.10 | 356.40 | 359.96 | 363.56 | 367.20 | 370.87 | 374.58 | 378.33 | 382.11 | 385.93 | 389.79 | 389.79 |
| 79 | | | | | | | | | | | | |
| Electrical cost | 29.70 | 119.14 | 126.20 | 133.86 | 141.89 | 150.41 | 159.43 | 169.00 | 179.14 | 189.88 | 201.28 | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | |
| Operating savings | 59.32 | 232.26 | 228.43 | 224.19 | 219.52 | 214.39 | 208.77 | 202.63 | 195.94 | 188.66 | 180.76 | |
| Inv tax credit 10% | 65.05 | | | | | | | | | | | |
| Deemed Cap. cost | 592.65 | | | | | | | | | | | |
| less CCA | 148.16 | 296.33 | 148.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Taxable income | -88.85 | -64.06 | 80.27 | 224.19 | 219.52 | 214.39 | 208.77 | 202.63 | 195.94 | 188.66 | 180.76 | |
| less tax payable | -39.98 | -28.83 | 36.12 | 100.89 | 98.78 | 96.47 | 93.95 | 91.18 | 88.17 | 84.90 | 81.34 | |
| Net Income | -48.87 | -35.23 | 44.15 | 123.30 | 120.74 | 117.91 | 114.82 | 111.45 | 107.77 | 103.76 | 99.42 | |
| Add back CCA | 148.16 | 296.33 | 148.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| Inv tax credit | 0.00 | | | | | | | | | | | |
| Net inc cash flow | 99.30 | 261.09 | 192.31 | 123.30 | 120.74 | 117.91 | 114.82 | 111.45 | 107.77 | 103.76 | 99.42 | 99.42 |
| 42 | | | | | | | | | | | | |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .22 (to year 11)

Project Cost less ITC 592.65 x 1000 After tax present value= 593.42 (to year 11

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 28.41 | 28.70 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 | |
| " " " " $/cuM | 178.80 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 | |
| " " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 | |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 | |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 | |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 | |
| Average $per kwh | .017 | .01882 | .0191812 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 | |

AFTER TAX All Cash Flows Thousands of $/year CIPA Fig 2

Fuel $/kWh .017 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .26

Fuel steam $/MBTU 5.9 Proj.cost 1317.00 x 1000 hv in 1732.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 191.16 | 764.64 | 772.29 | 780.01 | 787.81 | 795.69 | 803.64 | 811.68 | 819.80 | 828.00 | 836.28 | 836.28 | 836. |
| Electrical cost | 59.57 | 238.27 | 252.57 | 267.72 | 283.79 | 300.81 | 318.86 | 337.99 | 358.27 | 379.77 | 402.56 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 131.59 | 521.37 | 514.47 | 506.77 | 498.24 | 488.80 | 478.40 | 466.99 | 454.49 | 440.84 | 425.96 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| Less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -164.73 | -71.28 | 218.14 | 506.77 | 498.24 | 488.80 | 478.40 | 466.99 | 454.49 | 440.84 | 425.96 | | |
| Less tax payable | -74.13 | -32.08 | 98.16 | 228.05 | 224.21 | 219.96 | 215.28 | 210.14 | 204.52 | 198.38 | 191.68 | | |
| Net income | -90.60 | -39.21 | 119.98 | 278.73 | 274.03 | 268.84 | 263.12 | 256.84 | 249.97 | 242.46 | 234.28 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | -131.70 | | | | | | | | | | | | |
| Net inc cash flow | 337.42 | 553.44 | 416.30 | 278.73 | 274.03 | 268.84 | 263.12 | 256.84 | 249.97 | 242.46 | 234.28 | 234.28 | 234. |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .242 (to year 11)

Project Cost 1317.00 x 1000 After tax present value= 1318.84 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 30.48 | 30.78 | 31.09 | 31.40 | 31.72 | 32.03 | 32.35 | 32.68 | 33.00 | 33.33 | |
| " " " $/cuM | 191.80 | 193.72 | 195.66 | 197.61 | 199.59 | 201.59 | 203.60 | 205.64 | 207.70 | 209.77 | |
| " " " $/MBTU | 4.84 | 4.89 | 4.94 | 4.98 | 5.03 | 5.08 | 5.14 | 5.19 | 5.24 | 5.29 | |
| Fuel cost dollars per GJ | 4.59 | 4.63 | 4.68 | 4.72 | 4.77 | 4.82 | 4.87 | 4.92 | 4.97 | 5.02 | |
| Steam heat cost $/MBTU | 5.90 | 5.96 | 6.02 | 6.08 | 6.14 | 6.20 | 6.26 | 6.33 | 6.39 | 6.45 | |
| Steam heat cost $/GJ | 5.59 | 5.65 | 5.70 | 5.76 | 5.82 | 5.88 | 5.94 | 6.00 | 6.06 | 6.12 | |
| Average $per kwh | .017 | .01882 | .0191812 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 | |

AFTER TAX  All Cash Flows Thousands of $/year  CSPA Fig 2

yr2 $/KWh .017  MBTU/hr output 16.2  000 hr/yr 8  Elec esc. 1.06  Fuel Esc. 1.01  20yr IRR .21

yr 2 steam $/MBTU 5  Proj.cost 1317.00 x 1000  kw in 1752.00  Cash flow assumed level after 11th year

Tax rate 0.45  COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 162.00 | 648.00 | 634.40 | 661.02 | 667.64 | 674.31 | 681.05 | 687.87 | 694.74 | 701.69 | 708.71 | 708.71 | 708. |
| Electrical cost | 59.57 | 238.27 | 252.57 | 267.72 | 283.79 | 300.81 | 318.86 | 337.99 | 358.27 | 379.77 | 402.56 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 102.43 | 404.73 | 396.66 | 387.79 | 378.06 | 367.42 | 355.81 | 343.17 | 329.44 | 314.53 | 298.40 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| Less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -193.89 | -187.92 | 100.34 | 387.79 | 378.06 | 367.42 | 355.81 | 343.17 | 329.44 | 314.53 | 298.40 | | |
| Less tax payable | -87.25 | -84.56 | 45.15 | 174.51 | 170.13 | 165.34 | 160.12 | 154.43 | 148.25 | 141.54 | 134.28 | | |
| Net Income | -106.64 | -103.36 | 55.19 | 213.28 | 207.93 | 202.08 | 195.70 | 188.74 | 181.19 | 172.99 | 164.12 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 189.68 | 489.29 | 351.51 | 213.28 | 207.93 | 202.08 | 195.70 | 188.74 | 181.19 | 172.99 | 164.12 | 164.12 | 164. |

.188 is discount rate which equates  Present value to project cost  Internal Rate of Return = .188  (to year 11)

Project Cost less ITC 1185.30 x 1000  After tax present value= 1183.00 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 25.03 | 26.09 | 26.35 | 26.61 | 26.88 | 27.15 | 27.42 | 27.69 | 27.97 | 28.25 | |
| " " " $/cuM | 162.54 | 164.17 | 165.81 | 167.47 | 169.14 | 170.84 | 172.54 | 174.27 | 176.01 | 177.77 | |
| " " " $/MBTU | 4.10 | 4.14 | 4.18 | 4.22 | 4.27 | 4.31 | 4.35 | 4.40 | 4.44 | 4.48 | |
| Fuel cost dollars per GJ | 3.89 | 3.93 | 3.96 | 4.00 | 4.04 | 4.08 | 4.13 | 4.17 | 4.21 | 4.25 | |
| Steam heat cost $/MBTU | 5.00 | 5.05 | 5.10 | 5.15 | 5.20 | 5.26 | 5.31 | 5.36 | 5.41 | 5.47 | |
| Steam heat cost $/GJ | 4.74 | 4.79 | 4.83 | 4.88 | 4.93 | 4.98 | 5.03 | 5.08 | 5.13 | 5.18 | |
| Average $per kwh | .017 | .01882 | .0191812 | .0202473 | .0214421 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 | |

AFTER TAX All Cash Flows Thousands of $/year CDPA Fig 2

yr 2 $/KWh .017 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .273

yr 1 steam $/MBTU 6 Proj.cost 1317.00 x 1000 ku in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings +5 | 194.40 | 777.60 | 785.38 | 793.23 | 801.16 | 809.17 | 817.27 | 825.44 | 833.69 | 842.03 | 850.45 | 850.45 | 850. |
| Electrical cost | 59.57 | 238.27 | 252.57 | 267.72 | 283.79 | 300.81 | 318.86 | 337.99 | 358.27 | 379.77 | 402.56 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 134.83 | 534.33 | 527.56 | 519.99 | 511.59 | 502.28 | 492.02 | 480.74 | 468.38 | 454.87 | 440.14 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| Less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -161.49 | -58.32 | 231.23 | 519.99 | 511.59 | 502.28 | 492.02 | 480.74 | 468.38 | 454.87 | 440.14 | | |
| Less tax payable | -72.67 | -26.24 | 104.05 | 234.00 | 230.21 | 226.03 | 221.41 | 216.33 | 210.77 | 204.69 | 198.06 | | |
| Net Income | -88.82 | -32.08 | 127.18 | 286.00 | 281.37 | 276.26 | 270.61 | 264.41 | 257.61 | 250.18 | 242.08 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow 39 | 207.50 | 560.57 | 423.50 | 286.00 | 281.37 | 276.26 | 270.61 | 264.41 | 257.61 | 250.18 | 242.08 | 242.08 | 242. |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .256 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1185.63 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 31.00 | 31.31 | 31.62 | 31.94 | 32.25 | 32.58 | 32.90 | 33.23 | 33.56 | 33.90 | |
| " " " " $/cuM | 195.05 | 197.00 | 198.97 | 200.96 | 202.97 | 205.00 | 207.05 | 209.12 | 211.22 | 213.33 | |
| " " " " $/MBTU | 4.92 | 4.97 | 5.02 | 5.07 | 5.12 | 5.17 | 5.22 | 5.27 | 5.33 | 5.38 | |
| Fuel cost dollars per GJ | 4.66 | 4.71 | 4.76 | 4.80 | 4.85 | 4.90 | 4.95 | 5.00 | 5.05 | 5.10 | |
| Steam heat cost $/MBTU | 6.00 | 6.06 | 6.12 | 6.18 | 6.24 | 6.31 | 6.37 | 6.43 | 6.50 | 6.56 | |
| Steam heat cost $/GJ | 5.69 | 5.74 | 5.80 | 5.86 | 5.92 | 5.98 | 6.04 | 6.10 | 6.16 | 6.22 | |
| Average $per kwh | .017 | .01882 | .0191812 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 | |

AFTER TAX All Cash Flows Thousands of $/year CBPA Fig 2

yr2 $/KWh .025 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .206

yr 2 steam $/MBTU 6 Proj.cost 1317.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 194.48 | 777.60 | 785.38 | 793.23 | 801.16 | 809.17 | 817.27 | 825.44 | 833.69 | 842.03 | 850.45 | 850.45 | 850. |
| 45 | | | | | | | | | | | | | |
| Electrical cost | 87.60 | 350.40 | 371.42 | 393.71 | 417.33 | 442.37 | 468.91 | 497.05 | 526.87 | 558.48 | 591.99 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 106.80 | 422.20 | 408.70 | 394.01 | 378.04 | 360.72 | 341.97 | 321.69 | 299.78 | 276.16 | 250.70 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| Less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -189.53 | -170.45 | 112.38 | 394.01 | 378.04 | 360.72 | 341.97 | 321.69 | 299.70 | 276.16 | 250.70 | | |
| less tax payable | -85.29 | -76.70 | 50.57 | 177.30 | 170.12 | 162.33 | 153.89 | 144.76 | 134.90 | 124.27 | 112.81 | | |
| Net Income | -104.24 | -93.75 | 61.81 | 216.70 | 207.92 | 198.40 | 188.00 | 176.93 | 164.00 | 151.89 | 137.00 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 192.09 | 498.90 | 358.13 | 216.70 | 207.92 | 198.40 | 188.00 | 176.93 | 164.00 | 151.89 | 137.00 | 137.00 | 137. |
| 00 | | | | | | | | | | | | | |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .187 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1183.44 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 31.00 | 31.31 | 31.62 | 31.94 | 32.25 | 32.58 | 32.90 | 33.23 | 33.56 | 33.90 | |
| " " " $/cuM | 195.05 | 197.00 | 198.97 | 200.96 | 202.97 | 205.00 | 207.05 | 209.12 | 211.22 | 213.33 | |
| " " " $/MBTU | 4.92 | 4.97 | 5.02 | 5.07 | 5.12 | 5.17 | 5.22 | 5.27 | 5.33 | 5.38 | |
| Fuel cost dollars per GJ | 4.66 | 4.71 | 4.76 | 4.80 | 4.85 | 4.90 | 4.95 | 5.00 | 5.05 | 5.10 | |
| Steam heat cost $/MBTU | 6.00 | 6.06 | 6.12 | 6.18 | 6.24 | 6.31 | 6.37 | 6.43 | 6.50 | 6.56 | |
| Steam heat cost $/GJ | 5.69 | 5.74 | 5.80 | 5.86 | 5.92 | 5.98 | 6.04 | 6.10 | 6.16 | 6.22 | |
| Average $per kwh | .025 | .0265 | .02889 | .0297754 | .0315619 | .0334556 | .0354630 | .0375988 | .0398462 | .0422370 | |

AFTER TAX All Cash Flows Thousands of $/year CBPA Fig 2

yr1 $/KWh .025 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .167

yr 2 steam $/MBTU 5.5 Proj.cost 1317.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 178.20 | 712.80 | 719.93 | 727.13 | 734.40 | 741.74 | 749.16 | 756.65 | 764.22 | 771.86 | 779.58 | 779.58 | 779. |
| 48 | | | | | | | | | | | | | |
| Electrical cost | 87.60 | 350.40 | 371.42 | 393.71 | 417.33 | 442.37 | 468.91 | 497.05 | 526.87 | 558.48 | 591.99 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 90.60 | 357.40 | 343.25 | 327.91 | 311.28 | 293.29 | 273.86 | 252.90 | 230.31 | 205.99 | 179.83 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| Less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -205.73 | -235.25 | 46.93 | 327.91 | 311.28 | 293.29 | 273.86 | 252.90 | 230.31 | 205.99 | 179.83 | | |
| Less tax payable | -92.58 | -105.86 | 21.12 | 147.56 | 140.08 | 131.98 | 123.24 | 113.81 | 103.64 | 92.69 | 80.92 | | |
| Net Income | -113.15 | -129.39 | 25.81 | 180.35 | 171.20 | 161.31 | 150.63 | 139.10 | 126.67 | 113.29 | 98.91 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 183.18 | 463.26 | 322.14 | 180.35 | 171.20 | 161.31 | 150.63 | 139.10 | 126.67 | 113.29 | 98.91 | 98.91 | 98. |
| 91 | | | | | | | | | | | | | |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .145 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1185.91 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 30.41 | 28.78 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 |
| " " " " $/cuM | 178.80 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 |
| " " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 |
| Average $per kwh | .825 | .8265 | .82989 | .8297754 | .8315619 | .8334556 | .8354638 | .8375988 | .8398462 | .8422370 |

AFTER TAX All Cash Flows Thousands of $/year CDPA Fig 2

yr2 $/KWh .025 MBTU/hr output 16.2 000 hr/yr 0 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .121

yr 2 steam $/MBTU 5 Proj.cost 1317.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 162.00 | 648.00 | 654.48 | 661.02 | 667.64 | 674.31 | 681.05 | 687.87 | 694.74 | 701.69 | 708.71 | 708.71 | 708. |
| 71 | | | | | | | | | | | | | |
| Electrical cost | 87.60 | 350.40 | 371.42 | 393.71 | 417.33 | 442.37 | 468.91 | 497.05 | 526.87 | 558.48 | 591.99 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 74.40 | 292.60 | 277.81 | 261.80 | 244.51 | 225.86 | 205.76 | 184.12 | 160.84 | 135.82 | 108.96 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1105.30 | | | | | | | | | | | | |
| less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -221.93 | -300.05 | -18.52 | 261.80 | 244.51 | 225.86 | 205.76 | 184.12 | 160.84 | 135.82 | 108.96 | | |
| less tax payable | -99.87 | -135.02 | -8.33 | 117.81 | 110.03 | 101.64 | 92.59 | 82.85 | 72.38 | 61.12 | 49.03 | | |
| Net Income | -122.06 | -165.03 | -10.19 | 143.99 | 134.48 | 124.22 | 113.17 | 101.26 | 88.46 | 74.70 | 59.93 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 174.27 | 427.62 | 286.14 | 143.99 | 134.48 | 124.22 | 113.17 | 101.26 | 88.46 | 74.70 | 59.93 | 59.93 | 59. |
| 93 | | | | | | | | | | | | | |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .097 (to year 11)

Project Cost less ITC 1105.30 x 1000 After tax present value= 1103.48 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 25.03 | 26.09 | 26.35 | 26.61 | 26.88 | 27.15 | 27.42 | 27.69 | 27.97 | 28.25 | |
| " " " $/cuM | 162.54 | 164.17 | 165.81 | 167.47 | 169.14 | 170.84 | 172.54 | 174.27 | 176.01 | 177.77 | |
| " " " $/MBTU | 4.18 | 4.14 | 4.18 | 4.22 | 4.27 | 4.31 | 4.35 | 4.40 | 4.44 | 4.48 | |
| Fuel cost dollars per GJ | 3.89 | 3.93 | 3.96 | 4.00 | 4.04 | 4.08 | 4.13 | 4.17 | 4.21 | 4.25 | |
| Steam heat cost $/MBTU | 5.00 | 5.05 | 5.10 | 5.15 | 5.20 | 5.26 | 5.31 | 5.36 | 5.41 | 5.47 | |
| Steam heat cost $/GJ | 4.74 | 4.79 | 4.83 | 4.88 | 4.93 | 4.98 | 5.03 | 5.08 | 5.13 | 5.18 | |
| Average $per kwh | .025 | .0265 | .02809 | .0297754 | .0315619 | .0334556 | .0354630 | .0375909 | .0398462 | .0422378 | |

AFTER TAX All Cash Flows Thousands of $/year CDPA Fig 2

yr2 $/KWh .02 MBTU/hr output 16.2 000 hr/yr 0 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .101

yr 2 steam $/MBTU 5 Proj.cost 1317.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 162.00 | 648.00 | 654.48 | 661.02 | 667.64 | 674.31 | 681.05 | 687.87 | 694.74 | 701.69 | 708.71 | 708.71 | 708. |
| 71 | | | | | | | | | | | | | |
| Electrical cost | 70.00 | 280.32 | 297.14 | 314.97 | 333.87 | 353.90 | 375.13 | 397.64 | 421.50 | 446.79 | 473.59 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 91.92 | 362.68 | 352.09 | 340.54 | 327.90 | 314.34 | 299.54 | 283.53 | 266.21 | 247.52 | 227.36 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -204.41 | -229.97 | 55.77 | 340.54 | 327.90 | 314.34 | 299.54 | 283.53 | 266.21 | 247.52 | 227.36 | | |
| less tax payable | -91.98 | -103.49 | 25.09 | 153.25 | 147.59 | 141.45 | 134.79 | 127.59 | 119.79 | 111.38 | 102.31 | | |
| Net Income | -112.42 | -126.48 | 30.67 | 187.30 | 180.39 | 172.88 | 164.75 | 155.94 | 146.42 | 136.13 | 125.05 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 183.90 | 466.17 | 327.00 | 187.30 | 180.39 | 172.88 | 164.75 | 155.94 | 146.42 | 136.13 | 125.05 | 125.05 | 125. |
| 05 | | | | | | | | | | | | | |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .157 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1186.05 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 25.03 | 26.09 | 26.35 | 26.61 | 26.88 | 27.15 | 27.42 | 27.69 | 27.97 | 28.25 | |
| " " " " $/cuM | 162.54 | 164.17 | 165.81 | 167.47 | 169.14 | 170.84 | 172.54 | 174.27 | 176.01 | 177.77 | |
| " " " " $/MBTU | 4.10 | 4.14 | 4.18 | 4.22 | 4.27 | 4.31 | 4.35 | 4.40 | 4.44 | 4.48 | |
| Fuel cost dollars per GJ | 3.89 | 3.93 | 3.96 | 4.00 | 4.04 | 4.08 | 4.13 | 4.17 | 4.21 | 4.25 | |
| Steam heat cost $/MBTU | 5.00 | 5.05 | 5.10 | 5.15 | 5.20 | 5.26 | 5.31 | 5.36 | 5.41 | 5.47 | |
| Steam heat cost $/GJ | 4.74 | 4.79 | 4.83 | 4.88 | 4.93 | 4.98 | 5.03 | 5.08 | 5.13 | 5.18 | |
| Average $per kwh | .02 | .0212 | .022472 | .0230283 | .0252495 | .0267645 | .0283784 | .0300726 | .0318778 | .0337896 | |

AFTER TAX All Cash Flows Thousands of $/year CAPA Fig 2

yr2 $/KWh .02 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .217

yr 2 steam $/MBTU 5.5 Proj.cost 1317.00 x 1000 hv in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 178.20 | 712.80 | 719.93 | 727.13 | 734.40 | 741.74 | 749.16 | 756.65 | 764.22 | 771.86 | 779.58 | 779.58 | 779. |
| 58 | | | | | | | | | | | | | |
| Electrical cost | 78.00 | 288.32 | 297.14 | 314.97 | 333.87 | 353.90 | 375.13 | 397.64 | 421.50 | 446.79 | 473.59 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 100.12 | 427.48 | 417.54 | 406.65 | 394.74 | 381.77 | 367.65 | 352.31 | 335.68 | 317.69 | 298.23 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -100.21 | -165.17 | 121.21 | 406.65 | 394.74 | 381.77 | 367.65 | 352.31 | 335.68 | 317.69 | 298.23 | | |
| less tax payable | -04.69 | -74.33 | 54.55 | 102.99 | 177.64 | 171.80 | 165.44 | 158.54 | 151.06 | 142.96 | 134.20 | | |
| Net Income | -103.51 | -90.84 | 66.67 | 223.66 | 217.11 | 209.97 | 202.21 | 193.77 | 184.63 | 174.73, | 164.03 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 192.01 | 501.01 | 362.99 | 223.66 | 217.11 | 209.97 | 202.21 | 193.77 | 184.63 | 174.73 | 164.03 | 164.03 | 164. |
| 03 | | | | | | | | | | | | | |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .196 (to year 11)

Project Cost less ITC 1185.30 x 1000 After tax present value= 1186.98 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid | $/bbl | 28.41 | 28.70 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 |
| " " " " | $/cuM | 178.00 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 |
| " " " " | $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 |
| Fuel cost dollars per GJ | | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 |
| Steam heat cost $/MBTU | | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 |
| Steam heat cost $/GJ | | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 |
| Average $per kwh | | .02 | .0212 | .022472 | .0238283 | .0252495 | .0267645 | .0283784 | .0300726 | .0318778 | .0337896 |

AFTER TAX All Cash Flows Thousands of $/year CBPA Fig 2

yr2 $/KWh .02 MBTU/hr output 16.2 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .25

yr 2 steam $/MBTU 6 Proj.cost 1317.00 x 1000 kw in 1752.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings +5 | 194.40 | 777.60 | 785.38 | 793.23 | 801.16 | 809.17 | 817.27 | 825.44 | 833.69 | 842.03 | 850.45 | 850.45 | 85 |
| Electrical cost | 70.00 | 280.32 | 297.14 | 314.97 | 333.87 | 353.90 | 375.13 | 397.64 | 421.50 | 446.79 | 473.59 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 124.32 | 492.28 | 482.99 | 472.75 | 461.51 | 449.20 | 435.75 | 421.10 | 405.16 | 387.85 | 369.10 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -172.01 | -100.37 | 186.66 | 472.75 | 461.51 | 449.20 | 435.75 | 421.10 | 405.16 | 387.85 | 369.10 | | |
| less tax payable | -77.40 | -45.17 | 84.00 | 212.74 | 207.68 | 202.14 | 196.09 | 189.49 | 182.32 | 174.53 | 166.09 | | |
| Net Income | -94.60 | -55.20 | 102.66 | 260.01 | 253.83 | 247.06 | 239.66 | 231.60 | 222.84 | 213.32 | 203.00 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow 00 | 201.72 | 537.45 | 398.99 | 260.01 | 253.83 | 247.06 | 239.66 | 231.60 | 222.84 | 213.32 | 203.00 | 203.00 | 203 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .232 (to year 11)

Project Cost 1185.30 x 1000 After tax present value= 1184.43 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 31.00 | 31.31 | 31.62 | 31.94 | 32.25 | 32.58 | 32.90 | 33.23 | 33.56 | 33.90 | |
| " " " $/cuM | 195.05 | 197.00 | 198.97 | 200.96 | 202.97 | 205.00 | 207.05 | 209.12 | 211.22 | 213.33 | |
| " " " $/MBTU | 4.92 | 4.97 | 5.02 | 5.07 | 5.12 | 5.17 | 5.22 | 5.27 | 5.33 | 5.38 | |
| Fuel cost dollars per GJ | 4.66 | 4.71 | 4.76 | 4.80 | 4.85 | 4.90 | 4.95 | 5.00 | 5.05 | 5.10 | |
| Steam heat cost $/MBTU | 6.00 | 6.06 | 6.12 | 6.18 | 6.24 | 6.31 | 6.37 | 6.43 | 6.50 | 6.56 | |
| Steam heat cost $/GJ | 5.69 | 5.74 | 5.80 | 5.86 | 5.92 | 5.98 | 6.04 | 6.10 | 6.16 | 6.22 | |
| Average $per kwh | .02 | .0212 | .022472 | .0230283 | .0253495 | .0267645 | .0283704 | .0300726 | .0318778 | .0337896 | |

AFTER TAX NET PRESENT VALUE  All Cash Flows Thousands of $/year  CBPA Fig 2

yr2 $/KWh .02  MBTU/hr output 16.2  000 hr/yr 8  Elec esc. 1.06  Fuel Esc. 1.01  20yr IRR .155

yr 2 steam $/MBTU 4.72  Proj.cost 1317.00 x 1000  kw in 1752.00  Cash flow assumed level after 11th year

Tax rate 0.45  COP = 2.799222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 02 | 152.93 | 611.71 | 617.83 | 624.01 | 630.25 | 636.55 | 642.92 | 649.34 | 655.84 | 662.40 | 669.02 | 669.02 | 669 |
| Electrical cost | 78.00 | 288.32 | 297.14 | 314.97 | 333.87 | 353.90 | 375.13 | 397.64 | 421.50 | 446.79 | 473.59 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 82.05 | 326.39 | 315.44 | 303.53 | 290.59 | 276.57 | 261.40 | 245.00 | 227.30 | 208.22 | 187.67 | | |
| Inv tax credit 10% | 131.70 | | | | | | | | | | | | |
| Deemed Cap. cost | 1185.30 | | | | | | | | | | | | |
| less CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -213.48 | -266.26 | 19.11 | 303.53 | 290.59 | 276.57 | 261.40 | 245.00 | 227.30 | 208.22 | 187.67 | | |
| less tax payable | -96.06 | -119.82 | 8.60 | 136.59 | 130.77 | 124.46 | 117.63 | 110.25 | 102.29 | 93.70 | 84.45 | | |
| Net Income | -117.41 | -146.44 | 10.51 | 166.94 | 159.83 | 152.12 | 143.77 | 134.75 | 125.02 | 114.52 | 103.22 | | |
| Add back CCA | 296.33 | 592.65 | 296.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 131.70 | | | | | | | | | | | | |
| Net inc cash flow 22 | 310.61 | 446.21 | 306.84 | 166.94 | 159.83 | 152.12 | 143.77 | 134.75 | 125.02 | 114.52 | 103.22 | 103.22 | 103. |

IRR is discount rate which equates  Present value to project cost  Internal Rate of Return = .129  (to year 11)

Project Cost  1317.00 x 1000  After tax present value= 1317.44 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 24.38 | 24.63 | 24.87 | 25.12 | 25.37 | 25.63 | 25.88 | 26.14 | 26.40 | 26.67 | |
| " " " " $/cuM | 153.44 | 154.98 | 156.53 | 158.09 | 159.67 | 161.27 | 162.88 | 164.51 | 166.16 | 167.82 | |
| " " " " $/MBTU | 3.87 | 3.91 | 3.95 | 3.99 | 4.03 | 4.07 | 4.11 | 4.15 | 4.19 | 4.23 | |
| Fuel cost dollars per GJ | 3.67 | 3.71 | 3.74 | 3.78 | 3.82 | 3.86 | 3.89 | 3.93 | 3.97 | 4.01 | |
| Steam heat cost $/MBTU | 4.72 | 4.77 | 4.81 | 4.86 | 4.91 | 4.96 | 5.01 | 5.06 | 5.11 | 5.16 | |
| Steam heat cost $/GJ | 4.47 | 4.52 | 4.56 | 4.61 | 4.66 | 4.70 | 4.75 | 4.80 | 4.84 | 4.89 | |
| Average $per kwh | .02 | .0212 | .022472 | .0238283 | .0252495 | .0267645 | .0283784 | .0300726 | .0318778 | .0337896 | |

AFTER TAX All Cash Flows Thousands of $/year

yr2 $/KWh .825 MBTU/hr output 32.4 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .255

yr 2 steam $/MBTU 6 Proj.cost 2100.00 x 1000 kw in 3504.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 00 | 300.00 | 1555.20 | 1570.75 | 1586.46 | 1602.32 | 1618.35 | 1634.53 | 1650.00 | 1667.30 | 1604.06 | 1700.90 | 1700.90 | 1700. |
| Electrical cost | 175.20 | 700.00 | 742.05 | 707.42 | 834.66 | 004.74 | 937.03 | 994.10 | 1053.74 | 1116.97 | 1103.99 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 213.60 | 049.40 | 022.05 | 793.53 | 761.07 | 727.53 | 690.32 | 650.00 | 606.61 | 559.70 | 509.16 | | |
| Inv tax credit 10% | 210.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 1090.00 | | | | | | | | | | | | |
| less CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -250.90 | -95.60 | 350.15 | 793.53 | 761.07 | 727.53 | 690.32 | 650.00 | 606.61 | 559.70 | 509.16 | | |
| less tax payable | -116.51 | -43.02 | 157.57 | 357.09 | 342.04 | 327.39 | 310.64 | 292.53 | 272.97 | 251.07 | 229.12 | | |
| Net Income | -142.40 | -52.50 | 192.50 | 436.44 | 419.03 | 400.14 | 379.60 | 357.54 | 333.63 | 307.04 | 200.04 | | |
| Add back CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow 04 | 330.11 | 092.42 | 665.00 | 436.44 | 419.03 | 400.14 | 379.60 | 357.54 | 333.63 | 307.04 | 200.04 | 200.04 | 200 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .24 (to year 11)

Project Cost less ITC 1090.00 x 1000 After tax present value= 1091.40 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .02

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 31.00 | 31.31 | 31.62 | 31.94 | 32.25 | 32.50 | 32.90 | 33.23 | 33.56 | 33.90 | |
| " " " $/cuM | 195.05 | 197.00 | 190.97 | 200.96 | 202.97 | 205.00 | 207.05 | 209.12 | 211.22 | 213.33 | |
| " " " $/MBTU | 4.92 | 4.97 | 5.02 | 5.07 | 5.12 | 5.17 | 5.22 | 5.27 | 5.33 | 5.30 | |
| Fuel cost dollars per GJ | 4.66 | 4.71 | 4.76 | 4.00 | 4.05 | 4.90 | 4.95 | 5.00 | 5.05 | 5.10 | |
| Steam heat cost $/MBTU | 6.00 | 6.06 | 6.12 | 6.10 | 6.24 | 6.31 | 6.37 | 6.43 | 6.50 | 6.56 | |
| Steam heat cost $/GJ | 5.69 | 5.74 | 5.00 | 5.06 | 5.92 | 5.90 | 6.04 | 6.10 | 6.16 | 6.22 | |
| Average $per kwh | .025 | .0265 | .02009 | .0297754 | .0315619 | .0334556 | .0354630 | .0375900 | .0390462 | .0422370 | |

AFTER TAX All Cash Flows Thousands of $/year

yr2 $/KWh .825 MBTU/hr output 32.4 000 hr/yr 0 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .162

yr 2 steam $/MBTU 5 Proj.cost 2100.00 x 1000 kw in 3504.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 42 | 324.00 | 1296.00 | 1308.96 | 1322.05 | 1335.27 | 1348.62 | 1362.11 | 1375.73 | 1389.49 | 1403.38 | 1417.42 | 1417.42 | 1417 |
| Electrical cost | 175.20 | 700.00 | 742.05 | 787.42 | 834.66 | 884.74 | 937.83 | 994.10 | 1053.74 | 1116.97 | 1183.99 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 148.80 | 590.20 | 560.86 | 529.12 | 494.82 | 457.80 | 417.90 | 374.93 | 328.71 | 279.03 | 225.67 | | |
| Inv tax credit 10% | 210.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 1890.00 | | | | | | | | | | | | |
| less CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -323.70 | -354.80 | 88.36 | 529.12 | 494.82 | 457.80 | 417.90 | 374.93 | 328.71 | 279.03 | 225.67 | | |
| less tax payable | -145.67 | -159.66 | 39.76 | 238.10 | 222.67 | 206.01 | 188.05 | 168.72 | 147.92 | 125.56 | 101.55 | | |
| Net Income | -178.04 | -195.14 | 48.60 | 291.02 | 272.15 | 251.79 | 229.84 | 206.21 | 180.79 | 153.46 | 124.12 | | |
| Add back CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow 12 | 294.47 | 749.86 | 521.10 | 291.02 | 272.15 | 251.79 | 229.84 | 206.21 | 180.79 | 153.46 | 124.12 | 124.12 | 124 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .143 (to year 11)

Project Cost less ITC 1890.00 x 1000 After tax present value= 1887.59 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 25.03 | 26.09 | 26.35 | 26.61 | 26.88 | 27.15 | 27.42 | 27.69 | 27.97 | 28.25 | |
| " " " $/cuM | 162.54 | 164.17 | 165.81 | 167.47 | 169.14 | 170.84 | 172.54 | 174.27 | 176.01 | 177.77 | |
| " " " $/MBTU | 4.18 | 4.14 | 4.18 | 4.22 | 4.27 | 4.31 | 4.35 | 4.40 | 4.44 | 4.48 | |
| Fuel cost dollars per GJ | 3.89 | 3.93 | 3.96 | 4.00 | 4.04 | 4.08 | 4.13 | 4.17 | 4.21 | 4.25 | |
| Steam heat cost $/MBTU | 5.00 | 5.05 | 5.10 | 5.15 | 5.20 | 5.26 | 5.31 | 5.36 | 5.41 | 5.47 | |
| Steam heat cost $/GJ | 4.74 | 4.79 | 4.83 | 4.88 | 4.93 | 4.98 | 5.03 | 5.08 | 5.13 | 5.18 | |
| Average $per kwh | .825 | .8265 | .82889 | .8297754 | .8315619 | .8334556 | .8354638 | .8375988 | .8398462 | .8422378 | |

AFTER TAX All Cash Flows Thousands of $/year

yr2 $/KWh .02 MBTU/hr output 32.4 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .226

yr 2 steam $/MBTU 5 Proj.cost 2100.00 x 1000 kw in 3504.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 324.00 | 1296.00 | 1388.96 | 1322.05 | 1335.27 | 1348.62 | 1362.11 | 1375.73 | 1389.49 | 1403.38 | 1417.42 | 1417.42 | 1417.42 |
| Electrical cost | 140.16 | 560.64 | 594.28 | 629.94 | 667.73 | 707.80 | 750.26 | 795.28 | 843.00 | 893.57 | 947.19 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 183.84 | 730.36 | 789.43 | 686.60 | 661.75 | 634.75 | 605.46 | 573.75 | 539.46 | 502.42 | 462.47 | | |
| Inv tax credit 10% | 210.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 1890.00 | | | | | | | | | | | | |
| less CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -288.66 | -214.64 | 236.93 | 686.60 | 661.75 | 634.75 | 605.46 | 573.75 | 539.46 | 502.42 | 462.47 | | |
| less tax payable | -129.90 | -96.59 | 106.62 | 308.97 | 297.79 | 285.64 | 272.46 | 258.19 | 242.76 | 226.09 | 208.11 | | |
| Net Income | -158.76 | -118.05 | 130.31 | 377.63 | 363.96 | 349.11 | 333.01 | 315.56 | 296.70 | 276.33 | 254.36 | | |
| Add back CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 313.74 | 826.95 | 602.81 | 377.63 | 363.96 | 349.11 | 333.01 | 315.56 | 296.70 | 276.33 | 254.36 | 254.36 | 254.36 |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .207 (to year 11)

Project Cost less ITC 1890.00 x 1000 After tax present value= 1891.35 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 25.83 | 26.09 | 26.35 | 26.61 | 26.88 | 27.15 | 27.42 | 27.69 | 27.97 | 28.25 |
| " " " $/cuM | 162.54 | 164.17 | 165.81 | 167.47 | 169.14 | 170.84 | 172.54 | 174.27 | 176.01 | 177.77 |
| " " " $/MBTU | 4.18 | 4.14 | 4.18 | 4.22 | 4.27 | 4.31 | 4.35 | 4.40 | 4.44 | 4.48 |
| Fuel cost dollars per GJ | 3.89 | 3.93 | 3.96 | 4.00 | 4.04 | 4.08 | 4.13 | 4.17 | 4.21 | 4.25 |
| Steam heat cost $/MBTU | 5.00 | 5.05 | 5.10 | 5.15 | 5.20 | 5.26 | 5.31 | 5.36 | 5.41 | 5.47 |
| Steam heat cost $/GJ | 4.74 | 4.79 | 4.83 | 4.88 | 4.93 | 4.98 | 5.03 | 5.08 | 5.13 | 5.18 |
| Average $per kwh | .02 | .0212 | .022472 | .0238283 | .0252495 | .0267645 | .0283784 | .0300726 | .0318778 | .0337896 |

AFTER TAX All Cash Flows Thousands of $/year

yr2 $/KWh .82 MBTU/hr output 32.4 000 hr/yr 8 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .383

yr 2 steam $/MBTU 6 Proj.cost 2100.00 x 1000 kw in 3504.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings 00 | 388.00 | 1555.20 | 1570.75 | 1586.46 | 1602.32 | 1618.35 | 1634.53 | 1650.00 | 1667.30 | 1684.06 | 1700.90 | 1700.90 | 1700. |
| Electrical cost | 140.16 | 560.64 | 594.20 | 629.94 | 667.73 | 707.80 | 750.26 | 795.20 | 843.00 | 893.57 | 947.19 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 248.64 | 989.56 | 971.22 | 951.01 | 928.00 | 904.47 | 877.09 | 848.90 | 817.35 | 783.10 | 745.95 | | |
| Inv tax credit 10% | 210.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 1890.00 | | | | | | | | | | | | |
| less CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -223.86 | 44.56 | 498.72 | 951.01 | 928.00 | 904.47 | 877.09 | 848.90 | 817.35 | 783.10 | 745.95 | | |
| less tax payable | -100.74 | 20.05 | 224.43 | 427.96 | 417.96 | 407.01 | 395.05 | 382.00 | 367.81 | 352.39 | 335.68 | | |
| Net Income | -123.12 | 24.51 | 274.30 | 523.06 | 510.04 | 497.46 | 482.04 | 466.09 | 449.54 | 430.70 | 410.27 | | |
| Add back CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow 27 | 349.38 | 969.51 | 746.00 | 523.06 | 510.04 | 497.46 | 482.04 | 466.09 | 449.54 | 430.70 | 410.27 | 410.27 | 410. |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .289 (to year 11)

Project Cost less ITC 1890.00 x 1000 After tax present value= 1892.56 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 31.00 | 31.31 | 31.62 | 31.94 | 32.25 | 32.58 | 32.90 | 33.23 | 33.56 | 33.90 | |
| " " " $/cuM | 195.05 | 197.00 | 198.97 | 200.96 | 202.97 | 205.00 | 207.05 | 209.12 | 211.22 | 213.33 | |
| " " " $/MBTU | 4.92 | 4.97 | 5.02 | 5.07 | 5.12 | 5.17 | 5.22 | 5.27 | 5.33 | 5.38 | |
| Fuel cost dollars per GJ | 4.66 | 4.71 | 4.76 | 4.80 | 4.85 | 4.90 | 4.95 | 5.00 | 5.05 | 5.10 | |
| Steam heat cost $/MBTU | 6.00 | 6.06 | 6.12 | 6.18 | 6.24 | 6.31 | 6.37 | 6.43 | 6.50 | 6.56 | |
| Steam heat cost $/GJ | 5.69 | 5.74 | 5.80 | 5.86 | 5.92 | 5.98 | 6.04 | 6.10 | 6.16 | 6.22 | |
| Average $per kwh | .02 | .0212 | .022472 | .0230283 | .0252495 | .0267645 | .0283784 | .0300726 | .0318778 | .0337896 | |

AFTER TAX All Cash Flows Thousands of $/year

yr 2 $/kWh .017 MBTU/hr output 32.4 000 hr/yr 0 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .329

yr 2 steam $/MBTU 6 Proj.cost 2100.00 x 1000 kw in 2504.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings $0 | 388.00 | 1335.28 | 1378.75 | 1386.46 | 1402.32 | 1410.35 | 1434.53 | 1450.00 | 1467.30 | 1484.86 | 1700.90 | 1700.90 | 1700 |
| Electrical cost | 119.14 | 476.54 | 505.14 | 535.44 | 567.57 | 601.63 | 637.72 | 676.99 | 716.55 | 759.54 | 805.11 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 269.66 | 1073.66 | 1068.37 | 1045.50 | 1028.96 | 1010.64 | 990.43 | 968.19 | 943.00 | 917.13 | 888.03 | | |
| Inv tax credit 10% | 210.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 1890.00 | | | | | | | | | | | | |
| Less CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -202.84 | 128.66 | 507.87 | 1045.50 | 1028.96 | 1010.64 | 990.43 | 968.19 | 943.00 | 917.13 | 000.03 | | |
| Less tax payable | -91.20 | 57.90 | 204.54 | 470.40 | 463.03 | 454.79 | 445.69 | 435.60 | 424.71 | 412.71 | 399.61 | | |
| Net Income | -111.56 | 70.76 | 323.33 | 575.03 | 565.93 | 555.05 | 544.73 | 532.50 | 519.09 | 504.42 | 488.42 | | |
| Add back CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow $2 | 360.94 | 1015.76 | 795.03 | 575.03 | 565.93 | 555.05 | 544.73 | 532.50 | 519.09 | 504.42 | 488.42 | 488.42 | 488. |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .316 (to year 11)

Project Cost less ITC 1890.00 x 1000 After tax present value= 1891.00 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 31.00 | 31.31 | 31.62 | 31.94 | 32.25 | 32.58 | 32.90 | 33.23 | 33.56 | 33.90 | |
| " " " $/cuM | 195.05 | 197.00 | 198.97 | 200.96 | 202.97 | 205.00 | 207.05 | 209.12 | 211.22 | 213.33 | |
| " " " $/MBTU | 4.92 | 4.97 | 5.02 | 5.07 | 5.12 | 5.17 | 5.22 | 5.27 | 5.33 | 5.38 | |
| Fuel cost dollars per GJ | 4.66 | 4.71 | 4.76 | 4.80 | 4.85 | 4.90 | 4.95 | 5.00 | 5.05 | 5.10 | |
| Steam heat cost $/MBTU | 6.00 | 6.06 | 6.12 | 6.18 | 6.24 | 6.31 | 6.37 | 6.43 | 6.50 | 6.56 | |
| Steam heat cost $/GJ | 5.69 | 5.74 | 5.80 | 5.86 | 5.92 | 5.98 | 6.04 | 6.10 | 6.16 | 6.22 | |
| Average $per kwh | .017 | .01002 | .0191012 | .0202473 | .0214621 | .0227490 | .0241140 | .0255617 | .0270954 | .0287211 | |

AFTER TAX All Cash Flows Thousands of $/year

yr 2 $/KWh .017 MBTU/hr output 32.4 000 hr/yr 0 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .257

yr 2 steam $/MBTU 5 Proj.cost 2188.00 x 1000 ku in 3504.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 2.709222

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 324.00 | 1296.00 | 1388.96 | 1322.05 | 1335.27 | 1348.62 | 1362.11 | 1375.73 | 1389.49 | 1403.38 | 1417.42 | 1417.42 | 1417. |
| 42 | | | | | | | | | | | | | |
| Electrical cost | 119.14 | 476.54 | 505.14 | 535.44 | 567.57 | 601.63 | 637.72 | 675.99 | 716.55 | 759.54 | 805.11 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 204.86 | 814.46 | 798.57 | 781.09 | 761.91 | 740.92 | 718.00 | 693.04 | 665.91 | 636.46 | 604.55 | | |
| Inv tax credit 10% | 218.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 1090.00 | | | | | | | | | | | | |
| less CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -267.64 | -130.54 | 326.07 | 781.09 | 761.91 | 740.92 | 718.00 | 693.04 | 665.91 | 636.46 | 604.55 | | |
| less tax payable | -120.44 | -58.74 | 146.73 | 351.49 | 342.86 | 333.41 | 323.10 | 311.87 | 299.66 | 286.41 | 272.05 | | |
| Net Income | -147.20 | -71.80 | 179.34 | 429.60 | 419.05 | 407.51 | 394.90 | 381.17 | 366.25 | 350.05 | 332.50 | | |
| Add back CCA | 472.50 | 945.00 | 472.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Inv tax credit | 0.00 | | | | | | | | | | | | |
| Net inc cash flow | 325.30 | 873.20 | 651.84 | 429.60 | 419.05 | 407.51 | 394.90 | 381.17 | 366.25 | 350.05 | 332.50 | 332.50 | 332. |
| 50 | | | | | | | | | | | | | |

IRR is discount rate which equates Present value to project cost Internal Rate of Return = .24 (to year 11)

Project Cost less ITC 1090.00 x 1000 After tax present value= 1089.44 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid | $/bbl | 25.83 | 26.09 | 26.35 | 26.61 | 26.88 | 27.15 | 27.42 | 27.69 | 27.97 | 28.25 |
| " " " " | $/cuM | 162.54 | 164.17 | 165.81 | 167.47 | 169.14 | 170.84 | 172.54 | 174.27 | 176.01 | 177.77 |
| " " " " | $/MBTU | 4.10 | 4.14 | 4.18 | 4.22 | 4.27 | 4.31 | 4.35 | 4.40 | 4.44 | 4.48 |
| Fuel cost dollars per GJ | | 3.89 | 3.93 | 3.96 | 4.00 | 4.04 | 4.08 | 4.13 | 4.17 | 4.21 | 4.25 |
| Steam heat cost $/MBTU | | 5.00 | 5.05 | 5.10 | 5.15 | 5.20 | 5.26 | 5.31 | 5.36 | 5.41 | 5.47 |
| Steam heat cost $/GJ | | 4.74 | 4.79 | 4.83 | 4.88 | 4.93 | 4.98 | 5.03 | 5.08 | 5.13 | 5.18 |
| Average $per kwh | | .017 | .01882 | .0191812 | .0202473 | .0214621 | .0227498 | .0241148 | .0255617 | .0270954 | .0287211 |

AFTER TAX NET PRESENT VALUE  All Cash Flows Thousands of $/year  CSPA Fig 2

yr2 $/KWh .83  MBTU/hr output 16.2  000 hr/yr 8  Elec esc. 1.06  Fuel Esc. 1.01  20yr IRR .172

yr 2 steam $/MBTU 5.9  Proj.cost 1317.00 x 1000  kw in 1500.00  Cash flow assumed level after 11th year

Tax rate 0.45  COP = 3.004150

| year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 191.16 | 764.64 | 772.29 | 780.01 | 787.81 | 795.69 | 803.64 | 811.68 | 819.80 | 828.00 | 836.28 | 836.28 | 836. |
| 28 | | | | | | | | | | | | | |
| Electrical cost | 94.00 | 379.20 | 401.95 | 426.07 | 451.63 | 478.73 | 507.46 | 537.90 | 570.18 | 604.39 | 640.65 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 96.36 | 388.44 | 365.00 | 348.43 | 330.39 | 310.00 | 289.01 | 267.00 | 242.59 | 216.22 | 187.87 | | |
| Inv tax credit 7% | 92.19 | | | | | | | | | | | | |
| Deemed Cap. cost | 1224.01 | | | | | | | | | | | | |
| less CCA | 306.20 | 612.41 | 306.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | | |
| Taxable income | -209.04 | -231.97 | 50.00 | 340.43 | 330.39 | 310.00 | 209.01 | 267.00 | 242.59 | 216.22 | 187.87 | | |
| less tax payable | -94.43 | -104.30 | 26.50 | 156.79 | 140.67 | 139.90 | 130.41 | 120.19 | 109.16 | 97.30 | 04.54 | | |
| Net Income | -115.41 | -127.50 | 32.39 | 191.64 | 101.71 | 170.90 | 159.39 | 146.09 | 133.42 | 110.92 | 103.33 | | |
| Add back CCA | 306.20 | 612.41 | 306.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Net inc cash flow | 190.79 | 404.02 | 330.59 | 191.64 | 101.71 | 170.90 | 159.39 | 146.09 | 133.42 | 110.92 | 103.33 | 103.33 | 103. |
| 33 | | | | | | | | | | | | | |

IRR is discount rate which equates Net present value to project cost  Discount Rate = .15 (to year 11)

Deemed Project Cost 1224.01 x 1000  After tx Net present value 1226.43 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 30.40 | 30.70 | 31.09 | 31.40 | 31.72 | 32.03 | 32.35 | 32.60 | 33.00 | 33.33 |
| " " " $/cuM | 191.00 | 193.72 | 195.66 | 197.61 | 199.59 | 201.59 | 203.60 | 205.64 | 207.70 | 209.77 |
| " " " $/MBTU | 4.04 | 4.09 | 4.14 | 4.10 | 5.03 | 5.00 | 5.14 | 5.19 | 5.24 | 5.29 |
| Fuel cost dollars per GJ | 4.59 | 4.63 | 4.60 | 4.72 | 4.77 | 4.02 | 4.07 | 4.12 | 4.17 | 5.02 |
| Steam heat cost $/MBTU | 5.90 | 5.96 | 6.02 | 6.00 | 6.14 | 6.20 | 6.26 | 6.33 | 6.39 | 6.45 |
| Steam heat cost $/GJ | 5.59 | 5.65 | 5.70 | 5.76 | 5.02 | 5.00 | 5.94 | 6.00 | 6.06 | 6.12 |
| Average $per kwh | .03 | .0310 | .0337000 | .0357305 | .0370743 | .0401460 | .0425556 | .0451009 | .0470154 | .0506044 |

AFTER TAX NET PRESENT VALUE  All Cash Flows Thousands of $/year  Gatineau phase 2

yr 2 $/KWh .025  MBTU/hr output 16.2  000 hr/yr 8  Elec esc. 1.06  Fuel Esc. 1.01  20yr IRR .215

yr 2 steam $/MBTU 5.9  Proj.cost 1317.00 x 1000  kw in 1500.00  Cash flow assumed level after 11th year

Tax rate 0.45  COP = 3.004150

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 191.16 | 764.64 | 772.29 | 780.01 | 787.81 | 795.69 | 803.64 | 811.68 | 819.80 | 828.00 | 836.28 | 836.28 | 836. |
| 28 | | | | | | | | | | | | | |
| Electrical cost | 79.00 | 316.00 | 334.96 | 355.06 | 376.36 | 398.94 | 422.88 | 448.25 | 475.15 | 503.66 | 533.88 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.08 | 6.38 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 112.16 | 443.64 | 432.08 | 419.44 | 405.66 | 390.67 | 374.38 | 356.73 | 337.61 | 316.95 | 294.64 | | |
| Inv tax credit 7% | 92.19 | | | | | | | | | | | | |
| Deemed Cap. cost | 1224.81 | | | | | | | | | | | | |
| Less CCA | 306.20 | 612.41 | 306.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -194.04 | -168.77 | 125.87 | 419.44 | 405.66 | 390.67 | 374.38 | 356.73 | 337.61 | 316.95 | 294.64 | | |
| Less tax payable | -87.32 | -75.94 | 56.64 | 188.75 | 182.55 | 175.80 | 168.47 | 160.53 | 151.93 | 142.63 | 132.59 | | |
| Net Income | -106.72 | -92.82 | 69.23 | 230.69 | 223.11 | 214.87 | 205.91 | 196.20 | 185.69 | 174.32 | 162.05 | | |
| Add back CCA | 306.20 | 612.41 | 306.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Net inc cash flow | 199.48 | 519.58 | 375.43 | 230.69 | 223.11 | 214.87 | 205.91 | 196.20 | 185.69 | 174.32 | 162.05 | 162.05 | 162. |
| 05 | | | | | | | | | | | | | |

IRR is discount rate which equates Net present value to project cost  Discount Rate = .195 (to year 11)

Deemed Project Cost 1224.81 x 1000 After tx Net present value 1225.15 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 30.40 | 30.70 | 31.09 | 31.40 | 31.72 | 32.03 | 32.35 | 32.60 | 33.00 | 33.33 |
| " " " " $/cuM | 191.00 | 193.72 | 195.66 | 197.61 | 199.59 | 201.59 | 203.60 | 205.64 | 207.70 | 209.77 |
| " " " " $/MBTU | 4.04 | 4.09 | 4.14 | 4.18 | 5.03 | 5.08 | 5.14 | 5.19 | 5.24 | 5.29 |
| Fuel cost dollars per GJ | 4.59 | 4.63 | 4.68 | 4.72 | 4.77 | 4.82 | 4.87 | 4.92 | 4.97 | 5.02 |
| Steam heat cost $/MBTU | 5.90 | 5.96 | 6.02 | 6.08 | 6.14 | 6.20 | 6.26 | 6.33 | 6.39 | 6.45 |
| Steam heat cost $/GJ | 5.59 | 5.65 | 5.70 | 5.76 | 5.82 | 5.88 | 5.94 | 6.00 | 6.06 | 6.12 |
| Average $per kwh | .025 | .0265 | .02809 | .0297754 | .0315619 | .0334556 | .0354630 | .0375988 | .0398462 | .0422370 |

AFTER TAX PRESENT VALUE All Cash Flows Thousands of $/year Gatineau phase 2

yr2 $/KWh .02 MBTU/hr output 15 000 hr/yr 6.5 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .283

yr 2 steam $/MBTU 5.5 Proj.cost 000.00 x 1000 ku in 1362.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 1.226843

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings $ | 134.86 | 536.25 | 541.61 | 547.03 | 552.50 | 558.02 | 563.60 | 569.24 | 574.93 | 580.68 | 586.49 | 586.49 | 586 |
| Electrical cost | 44.27 | 177.86 | 187.60 | 198.94 | 210.00 | 223.53 | 236.95 | 251.16 | 266.23 | 282.21 | 299.14 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 89.00 | 354.19 | 348.60 | 342.57 | 335.03 | 328.41 | 320.20 | 311.30 | 301.66 | 291.09 | 279.59 | | |
| Inv tax credit 7% | 56.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 744.00 | | | | | | | | | | | | |
| less CCA | 186.00 | 372.00 | 186.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -96.20 | -17.81 | 162.60 | 342.57 | 335.03 | 328.41 | 320.20 | 311.30 | 301.66 | 291.09 | 279.59 | | |
| less tax payable | -43.29 | -8.01 | 73.21 | 154.16 | 151.12 | 147.79 | 144.12 | 140.12 | 135.75 | 130.99 | 125.82 | | |
| Net Income | -52.91 | -9.80 | 89.47 | 188.41 | 184.71 | 180.63 | 176.15 | 171.26 | 165.92 | 160.10 | 153.78 | | |
| Add back CCA | 186.00 | 372.00 | 186.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Net inc cash flow $ | 133.09 | 362.20 | 275.47 | 188.41 | 184.71 | 180.63 | 176.15 | 171.26 | 165.92 | 160.10 | 153.78 | 153.78 | 153 |

IRR is discount rate which equates present value to project cost Discount Rate = .265 (to year 11)

Deemed Project Cost 744.00 x 1000 After tx present value 749.26 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 28.41 | 28.78 | 28.98 | 29.27 | 29.57 | 29.86 | 30.16 | 30.46 | 30.77 | 31.07 | |
| " " " $/cuM | 178.00 | 180.59 | 182.39 | 184.22 | 186.06 | 187.92 | 189.80 | 191.70 | 193.61 | 195.55 | |
| " " " $/MBTU | 4.51 | 4.56 | 4.60 | 4.65 | 4.69 | 4.74 | 4.79 | 4.84 | 4.88 | 4.93 | |
| Fuel cost dollars per GJ | 4.27 | 4.32 | 4.36 | 4.40 | 4.45 | 4.49 | 4.54 | 4.58 | 4.63 | 4.68 | |
| Steam heat cost $/MBTU | 5.50 | 5.56 | 5.61 | 5.67 | 5.72 | 5.78 | 5.84 | 5.90 | 5.96 | 6.02 | |
| Steam heat cost $/GJ | 5.21 | 5.27 | 5.32 | 5.37 | 5.42 | 5.48 | 5.53 | 5.59 | 5.65 | 5.70 | |

AFTER TAX PRESENT VALUE All Cash Flows Thousands of $/year Gatineau phase 2

yr2 $/KWh .02 MBTU/hr output 15 000 hr/yr 6.5 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .225

yr 2 steam $/MBTU 4.72 Proj.cost 000.00 x 1000 kw in 1362.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 3.22b043

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 115.05 | 468.28 | 464.00 | 469.45 | 474.14 | 478.09 | 483.67 | 488.51 | 493.40 | 498.33 | 503.31 | 503.31 | 503. |
| 31 | | | | | | | | | | | | | |
| Electrical cost | 44.27 | 177.06 | 187.60 | 198.94 | 210.00 | 223.53 | 236.95 | 251.16 | 266.23 | 282.21 | 299.14 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 70.79 | 270.14 | 271.07 | 264.99 | 257.40 | 249.27 | 240.35 | 230.65 | 220.13 | 200.74 | 196.42 | | |
| Inv tax credit 7% | 56.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 744.00 | | | | | | | | | | | | |
| Less CCA | 106.00 | 372.00 | 106.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -115.22 | -93.06 | 05.07 | 264.99 | 257.40 | 249.27 | 240.35 | 230.65 | 220.13 | 200.74 | 196.42 | | |
| Less tax payable | -51.05 | -42.24 | 30.64 | 119.25 | 115.06 | 112.17 | 100.16 | 103.79 | 99.06 | 93.93 | 00.39 | | |
| Net Income | -63.37 | -51.62 | 47.23 | 145.75 | 141.61 | 137.10 | 132.19 | 126.06 | 121.07 | 114.01 | 100.03 | | |
| Add back CCA | 106.00 | 372.00 | 106.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Net inc cash flow | 122.63 | 320.30 | 233.23 | 145.75 | 141.61 | 137.10 | 132.19 | 126.06 | 121.07 | 114.01 | 100.03 | 106.03 | 100. |
| 03 | | | | | | | | | | | | | |

IRR is discount rate which equates present value to project cost Discount Rate = .205 (to year 11)

Deemed Project Cost 744.00 x 1000 After tx present value 744.01 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 24.30 | 24.63 | 24.07 | 25.12 | 25.37 | 25.63 | 25.00 | 26.14 | 26.40 | 26.67 | |
| " " " " $/cuM | 153.44 | 154.90 | 156.53 | 150.09 | 159.67 | 161.27 | 162.00 | 164.51 | 166.16 | 167.02 | |
| " " " " $/MBTU | 3.07 | 3.91 | 3.95 | 3.99 | 4.03 | 4.07 | 4.11 | 4.15 | 4.19 | 4.23 | |
| Fuel cost dollars per GJ | 3.67 | 3.71 | 3.74 | 3.70 | 3.02 | 3.06 | 3.09 | 3.93 | 3.97 | 4.01 | |
| Steam heat cost $/MBTU | 4.72 | 4.77 | 4.01 | 4.06 | 4.91 | 4.96 | 5.01 | 5.06 | 5.11 | 5.16 | |
| Steam heat cost $/GJ | 4.47 | 4.52 | 4.56 | 4.61 | 4.66 | 4.70 | 4.75 | 4.00 | 4.04 | 4.09 | |

AFTER TAX PRESENT VALUE All Cash Flows Thousands of $/year Gatineau phase 2

yr2 $/KWh .017 MBTU/hr output 15 000 hr/yr 6.5 Elec esc. 1.05 Fuel Esc. 1.01 20yr IRR .34

yr 2 steam $/MBTU 6 Proj.cost 000.00 x 1000 kw in 1362.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 3.226843

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 146.25 | 585.00 | 590.85 | 596.76 | 602.73 | 608.75 | 614.84 | 620.99 | 627.20 | 633.47 | 639.81 | 639.81 | 639. |
| 91 | | | | | | | | | | | | | |
| Electrical cost | 37.63 | 150.50 | 150.03 | 165.93 | 174.22 | 182.93 | 192.08 | 201.69 | 211.77 | 222.36 | 233.48 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 108.62 | 429.50 | 427.57 | 425.32 | 422.71 | 419.74 | 416.30 | 412.60 | 408.39 | 403.73 | 398.57 | | |
| Inv tax credit 7% | 56.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 744.00 | | | | | | | | | | | | |
| less CCA | 186.00 | 372.00 | 186.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -77.38 | 57.50 | 241.57 | 425.32 | 422.71 | 419.74 | 416.30 | 412.60 | 408.39 | 403.73 | 398.57 | | |
| less tax payable | -34.82 | 25.87 | 108.71 | 191.39 | 190.22 | 188.88 | 187.37 | 185.67 | 183.78 | 181.68 | 179.36 | | |
| Net Income | -42.56 | 31.62 | 132.87 | 233.93 | 232.49 | 230.86 | 229.01 | 226.93 | 224.62 | 222.05 | 219.22 | | |
| Add back CCA | 186.00 | 372.00 | 186.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Net inc cash flow | 143.44 | 403.62 | 318.87 | 233.93 | 232.49 | 230.86 | 229.01 | 226.93 | 224.62 | 222.05 | 219.22 | 219.22 | 219. |
| 22 | | | | | | | | | | | | | |

IRR is discount rate which equates present value to project cost Discount Rate = .32 (to year 11)

Deemed Project Cost 744.00 x 1000 After tx present value 757.71 (to year 11)

Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 31.00 | 31.31 | 31.62 | 31.94 | 32.25 | 32.58 | 32.90 | 33.23 | 33.56 | 33.90 | |
| " " " $/cuM | 195.05 | 197.00 | 198.97 | 200.96 | 202.97 | 205.00 | 207.05 | 209.12 | 211.22 | 213.33 | |
| " " " $/MBTU | 4.92 | 4.97 | 5.02 | 5.07 | 5.12 | 5.17 | 5.22 | 5.27 | 5.33 | 5.38 | |
| Fuel cost dollars per GJ | 4.66 | 4.71 | 4.76 | 4.80 | 4.85 | 4.90 | 4.95 | 5.00 | 5.05 | 5.10 | |
| Steam heat cost $/MBTU | 6.00 | 6.06 | 6.12 | 6.18 | 6.24 | 6.31 | 6.37 | 6.43 | 6.50 | 6.56 | |
| Steam heat cost $/GJ | 5.69 | 5.74 | 5.80 | 5.86 | 5.92 | 5.98 | 6.04 | 6.10 | 6.16 | 6.22 | |
| Average $per kwh | .017 | .01785 | .0187425 | .0196796 | .0206636 | .0216968 | .0227816 | .0239207 | .0251167 | .0263726 | |

AFTER TAX . . All Cash Flows Thousands of $/year Gatineau phase 2 .

yr2 $/KWh .017 MBTU/hr output 15 000 hr/yr 6.5 Elec esc. 1.06 Fuel Esc. 1.01 20yr IRR .25

yr 2 steam $/MBTU 4.72 Proj.cost 000.00 x 1000 ku in 1362.00 Cash flow assumed level after 11th year

Tax rate 0.45 COP = 3.226043

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fuel savings | 115.05 | 460.20 | 464.00 | 469.45 | 474.14 | 478.09 | 483.67 | 488.51 | 493.40 | 498.33 | 503.31 | 503.31 | 503. |
| 31 | | | | | | | | | | | | | |
| Electrical cost | 37.63 | 150.50 | 159.53 | 169.10 | 179.25 | 190.00 | 201.40 | 213.49 | 226.30 | 239.00 | 254.27 | | |
| Maintenance cost | | 5.00 | 5.25 | 5.51 | 5.79 | 6.00 | 6.30 | 6.70 | 7.04 | 7.39 | 7.76 | | |
| Operating savings | 77.42 | 304.70 | 300.02 | 294.03 | 289.11 | 282.00 | 275.09 | 268.32 | 260.06 | 251.07 | 241.29 | | |
| Inv tax credit 7% | 56.00 | | | | | | | | | | | | |
| Deemed Cap. cost | 744.00 | | | | | | | | | | | | |
| less CCA | 186.00 | 372.00 | 186.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Taxable income | -100.58 | -67.30 | 114.02 | 294.03 | 289.11 | 282.00 | 275.09 | 260.32 | 260.06 | 251.07 | 241.29 | | |
| less tax payable | -40.06 | -30.29 | 51.31 | 132.60 | 130.10 | 127.26 | 124.15 | 120.75 | 117.03 | 112.90 | 100.50 | | |
| Net Income | -59.72 | -37.02 | 62.71 | 162.16 | 159.01 | 155.54 | 151.74 | 147.50 | 143.03 | 130.09 | 132.71 | | |
| Add back CCA | 186.00 | 372.00 | 186.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Net inc cash flow | 126.20 | 334.90 | 240.71 | 162.16 | 159.01 | 155.54 | 151.74 | 147.50 | 143.03 | 130.09 | 132.71 | 132.71 | 132. |
| 71 | | | | | | | | | | | | | |

IRR is discount rate which equates present value to project cost Discount Rate = .23 (to year 11)

Deemed Project Cost 744.00 x 1000 After tx present value 747.01 (to year 11)

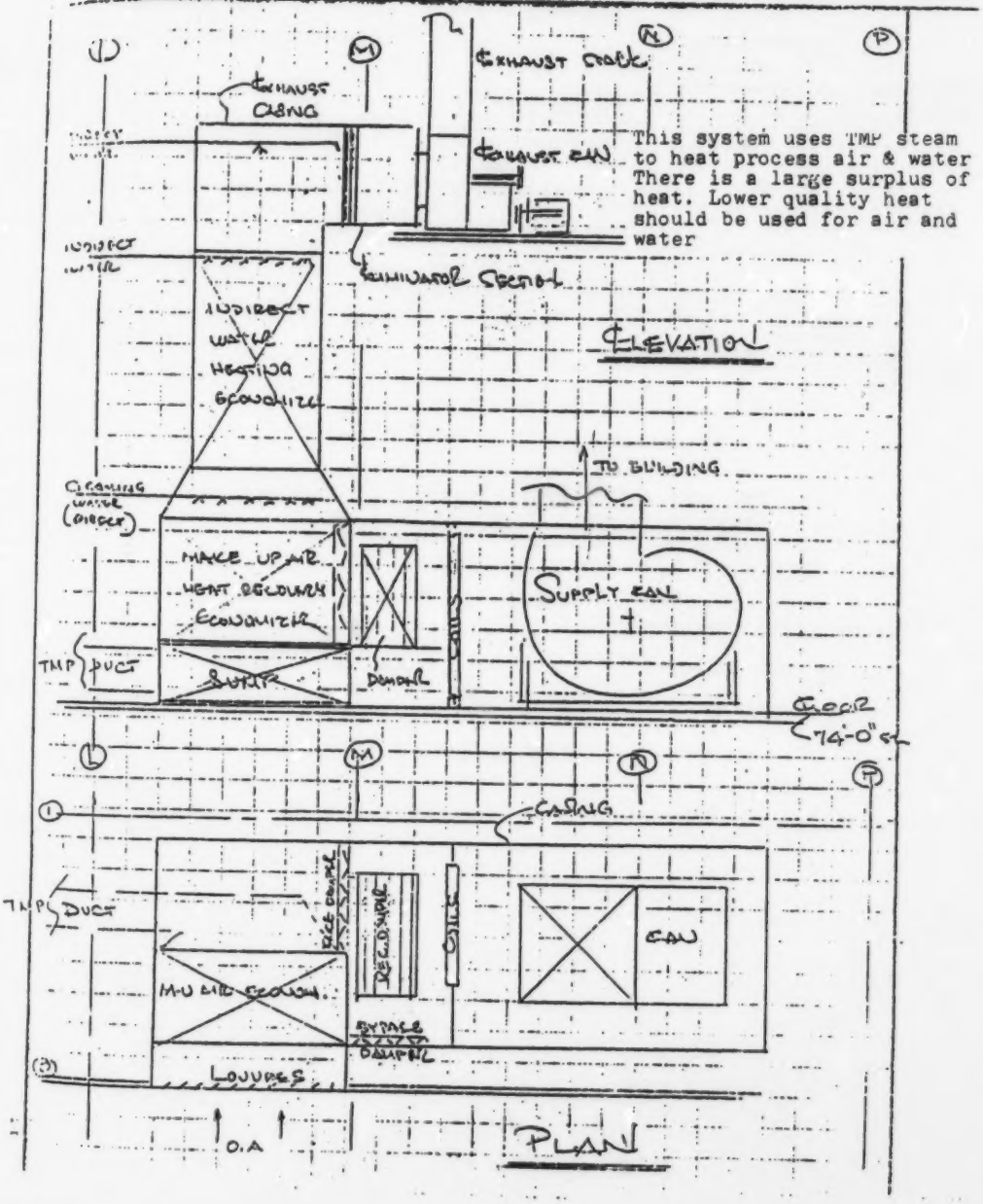
Corresponding fuel prices assuming overall efficiency of conversion from fuel to steam heat = .82

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heavy fuel oil-resid $/bbl | 24.30 | 24.63 | 24.07 | 25.12 | 25.37 | 25.63 | 25.00 | 26.14 | 26.40 | 26.67 | |
| " " " " $/cuM | 153.44 | 154.90 | 156.53 | 150.09 | 159.67 | 161.27 | 162.00 | 164.51 | 166.16 | 167.02 | |
| " " " " $/MBTU | 3.07 | 3.91 | 3.95 | 3.99 | 4.03 | 4.07 | 4.11 | 4.15 | 4.19 | 4.23 | |
| Fuel cost dollars per GJ | 3.67 | 3.71 | 3.74 | 3.70 | 3.02 | 3.06 | 3.09 | 3.93 | 3.97 | 4.01 | |
| Steam heat cost $/MBTU | 4.72 | 4.77 | 4.01 | 4.06 | 4.91 | 4.96 | 5.01 | 5.06 | 5.11 | 5.16 | |
| Steam heat cost $/GJ | 4.47 | 4.52 | 4.56 | 4.61 | 4.66 | 4.70 | 4.75 | 4.00 | 4.04 | 4.09 | |

ROSS AIR SYSTEMS DIVISION

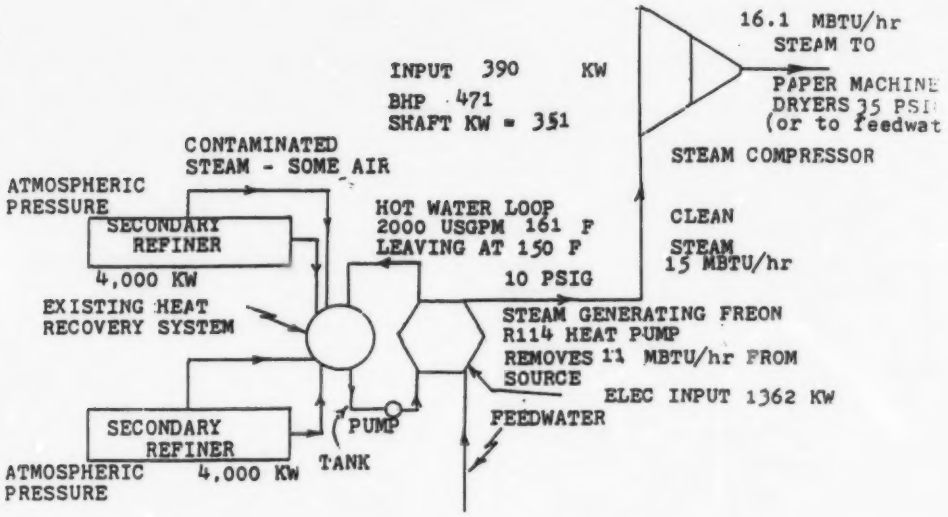
ENGINEERING DATA SHEET

CLIENT CONSUMERS POWER
AT DIRT FIELD
PROJECT HEAT RECOVERY SCRUBBER
DATE 2/18/77 CONT. NO. 01-7660-2 BY C.J.R.




This system uses TMP steam to heat process air & water There is a large surplus of heat. Lower quality heat should be used for air and water

Fig A-1




SIMPLIFIED

TMP STEAM HEAT RECOVERY USING STEAM GENERATING
FREON R114 HEAT PUMP AND STEAM COMPRESSOR

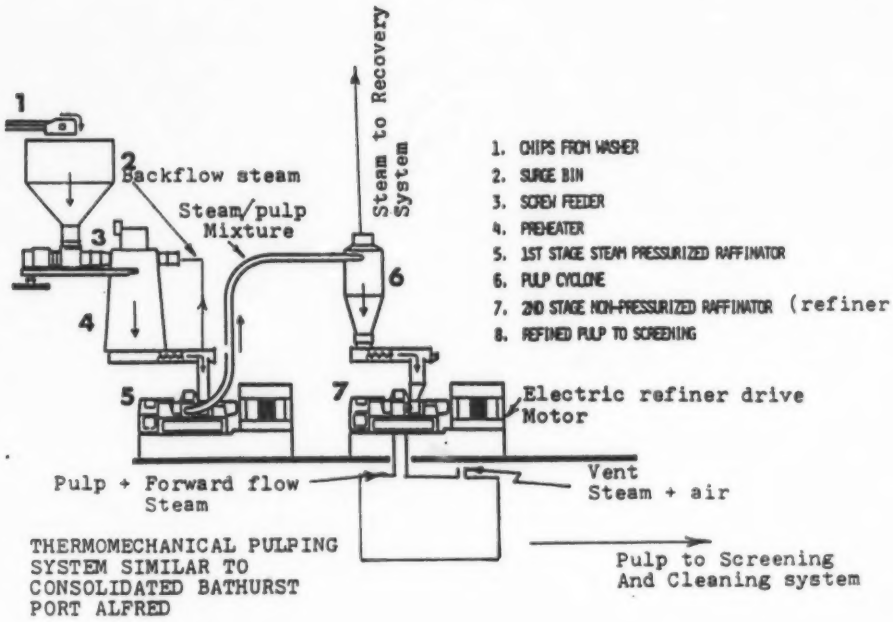
CONSOLIDATED BATHURST - PORT ALFRED

Cost $1.3 million

IRR (DCF ROI) 24%

G.A. ROBB ASSOCIATES

Fig A-2


1
2
Backflow steam
Steam/pulp
Mixture
3
4
5
6
7
Steam to Recovery System
1. CHIPS FROM WASHER
2. SURGE BIN
3. SCREW FEEDER
4. PREHEATER
5. 1ST STAGE STEAM PRESSURIZED RAFFINATOR
6. PULP CYCLONE
7. 2ND STAGE NON-PRESSURIZED RAFFINATOR (refiner
8. REFINED PULP TO SCREENING
Electric refiner drive
Motor
Pulp + Forward flow
Steam
Vent
Steam + air
THERMOMECHANICAL PULPING
SYSTEM SIMILAR TO
CONSOLIDATED BATHURST
PORT ALFRED
Pulp to Screening
And Cleaning system

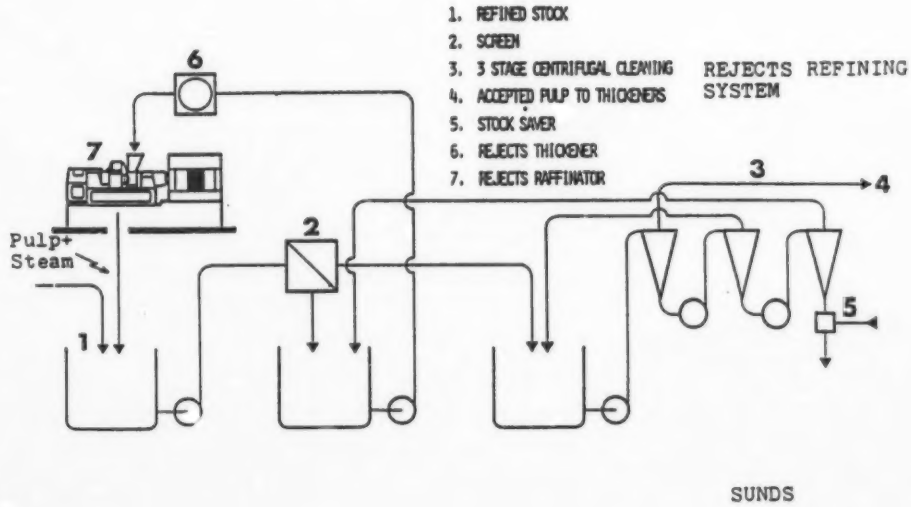

1. REFINED STOCK
2. SCREEN
3. 3 STAGE CENTRIFUGAL CLEANING
4. ACCEPTED PULP TO THICKENERS
5. STOCK SAVER
6. REJECTS THICKENER
7. REJECTS RAFFINATOR
REJECTS REFINING
SYSTEM
6
7
Pulp+
Steam
1
2
3
4
5
SUNDS

Fig A-3

# APPENDIX B

Cost Estimate for Steam Generating R114 Heat Pump System as in Fig 2 Appendix A

Installed with Steam Compressor at Consolidated Bathurst Port Alfred - La Baie Que

| | Thousands of Dollars | | |
|---|---|---|---|
| | Material | Labour | Total |
| Modification of heat recovey system | 10 | 5 | 15 |
| Hot water circulating pump (2000 USGPM) with motor | 15 | | 15 |
| Electrical for above - Starter and cable | 5 | | 5 |
| Installation of Circulating Pump (Mech & Elec) | 10 | 10 | 20 |
| Steam Generating Heat Pump With 2000 HP motor | | | 0 |
| All as Shop assembed Module on Skid | 600 | | 600 |
| Installation of heat pump | | | 0 |
| Concrete Pad 50ft x60ft (HtPmp & Comp) | 15 | 15 | 30 |
| Building | 30 | 10 | 40 |
| Electrical Starter and Cable | 50 | 10 | 60 |
| Feedwater Supply to Heat Pump | 10 | 10 | 20 |
| Installation and Piping for above | 10 | 5 | 15 |
| Centrifugal Steam Compressor (single stage) with | 185 | | 185 |
| 500 HP Motor | | | 0 |
| Compressor Installation (mech) | 10 | 10 | 20 |
| Compressor Installation (elec) | 40 | 20 | 60 |
| Steam line to Paper Machines and controls | 30 | 30 | 60 |
| | | | 0 |
| Sub Total | 1020 | 125 | 1145 |
| Contingencies and Escalation | 152 | 20 | 172 |
| Total | 1172 | 145 | 1317 |

Cost Estimate Steam Generating R114 Industrial Heat Pump

Temporary installation of Heat Pump

And Test Rig Assuming Availability of Elec. Supply

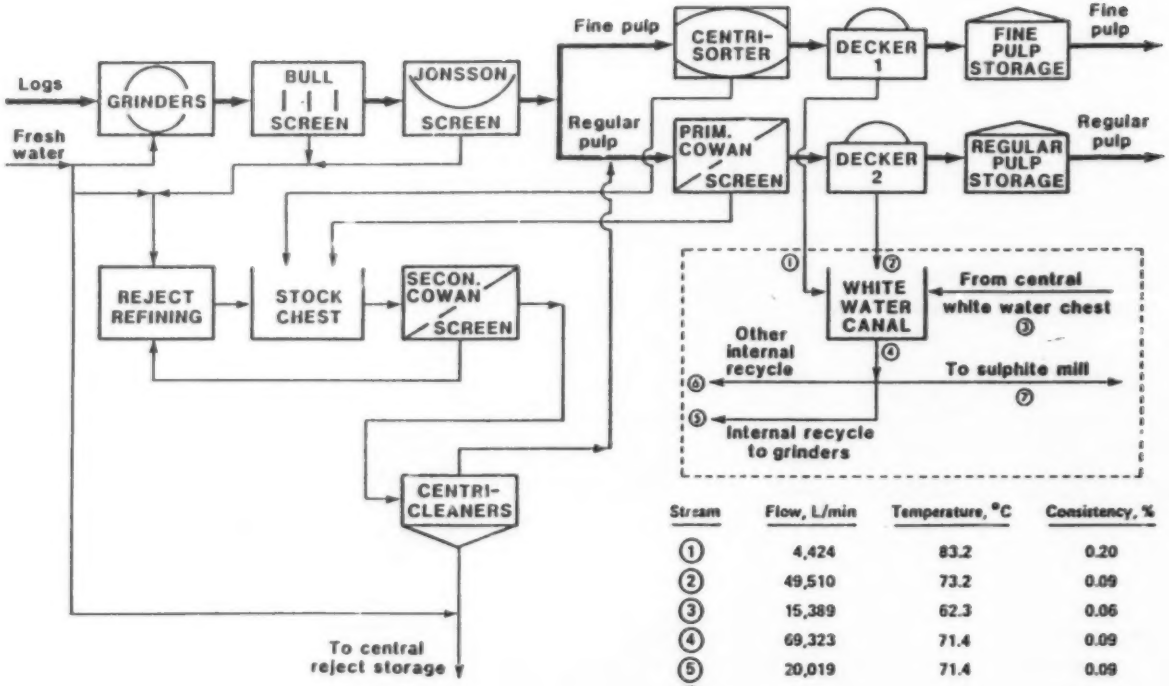
No Building

| | Material | Labour | |
|---|---|---|---|
| Heat Pump with 2000 HP motor | 600.00 | | 600.00 |
| Delivery and Temp Installation | 10.00 | 10.00 | 20.00 |
| Tank | 10.00 | | 10.00 |
| Piping | 10.00 | 10.00 | 20.00 |
| Pump | 15.00 | 5.00 | 15.00 |
| Electrical | 50.00 | 10.00 | 60.00 |
| Sub total | 695.00 | 35.00 | 725.00 |
| 15% Contingencies | 104.25 | 5.25 | 108.75 |
| TOTAL | 799.25 | 40.25 | 833.75 |

APPENDIX C

SCHEDULE

| | 1984 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Negotiation | | | | | | | | | | | |
| With mill | ******* | | | | | | | | | | |
| Design contracts | ******* | | | | | | | | | | |
| Selection of supplier | ** | | | | | | | | | | |
| Selection of Dev facilities | ******** | | | | | | | | | | |
| Prep funding proposals | ******** | | | | | | | | | | |
| Completion funding arrangements | *** | | | | | | | | | | |
| Identification of | | | | | | | | | | | |
| Development requirements | ******** | | | | | | | | | | |
| Building of heat pump | ********** | | | | | | | | | | |
| Testing & Development | ******** | | | | | | | | | | |
| Installation in demonstration mill | ********** | | | | | | | | | | |
| Monitoring and reporting | ********** | | | | | | | | | | |
| Financial requirements | $ 55000 | 105000 | 433000 | 331000 | 5000 | 5000 | 75000 | 100000 | 50000 | 50000 | |
| Total fiscal 84/85 | $ 925000 | | | | | | | | | | |
| Total fiscal 85/86 | $ 305000 | | | | | | | | | | |
| Grand Total | | | | | | | | | | $ | 1230000 |



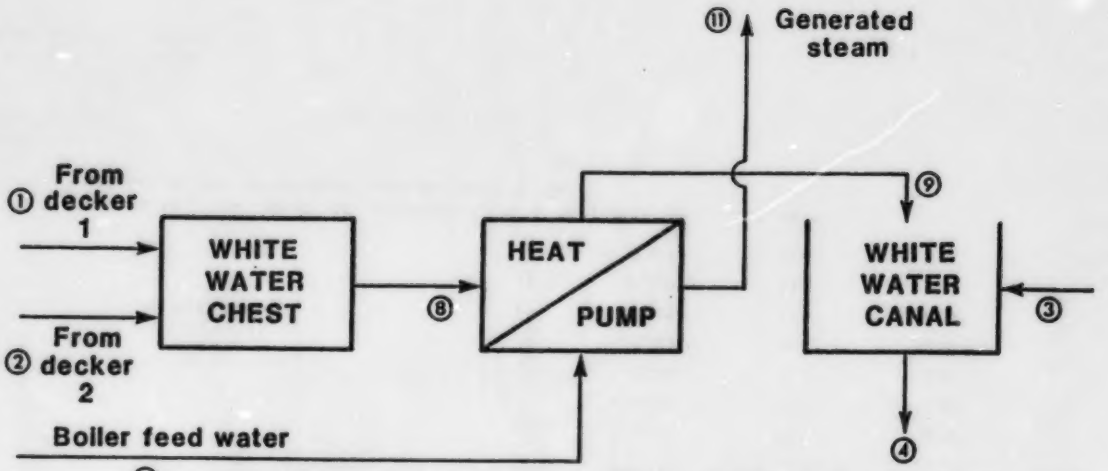

| Stream | Flow, L/min | Temperature, °C | Consistency, % |
|---|---|---|---|
| ① | 4,424 | 83.2 | 0.20 |
| ② | 49,510 | 73.2 | 0.09 |
| ③ | 15,389 | 62.3 | 0.06 |
| ④ | 69,323 | 71.4 | 0.09 |
| ⑤ | 20,019 | 71.4 | 0.09 |
| ⑥ | 41,780 | 71.4 | 0.09 |
| ⑦ | 7,524 | 71.4 | 0.09 |

Schematic flow sheet of groundwood mill including heat and mass balance of the white water system (case study).

Flow diagram of stone groundwood mill illustrating Grand' Mere and many other applications. Electrical energy which drives grinders appears as heat in white water

FROM PPRIC STUDY

PPRIC




Application of heat pump to extract heat from stone groundwood white water and generate process steam

| Stream | Flow, L/min | Temperature, °C | Consistency, % |
|---|---|---|---|
| ① | 4,424 | 83.2 | 0.20 |
| ② | 49,510 | 73.2 | 0.09 |
| ③ | 15,389 | 62.3 | 0.06 |
| ④ | 69,323 | 69.4 | 0.09 |
| ⑧ | 53,934 | 74.0 | 0.10 |
| ⑨ | 53,934 | 71.4 | 0.10 |
| ⑩ | 295 | 65.6 | 0 |
| ⑪ | 295 (water equivalent) | 147.2 | 0 |

Possible modification of white water system with integrated heat recovery by heat pump (case study).

-from same PPRIC study

PPRIC

APPENDIX E

CONSOLIDATED - BATHURST INC.

800 Dorchester Boulevard West, Montreal, Quebec H3B 1Y9 Telephone (514) 875-2160

Vice-President

Mail address: P.O. Box 69, Montreal H3C 2R5

May 27, 1983

Mr. G. A. Robb,
G. A. Robb Associates,
1855 Beattie Ave.,
Ottawa, Ont. K1H 5R7

Dear Mr. Robb,

I have your letter of May 20 covering your proposal to reduce energy through the use of heat pumps. Some of our work in this phase of energy conservation has been done with your group.

We will be interested in reviewing any suggested program and our Chief Engineer, Mr. T. E. Savoy, would coordinate any such program. The Consolidated-Bathurst Manufacturing Group has been interested in heat pump applications since 1950 but to date our success in this field has been very limited. We will be receptive to evaluating any program which could economically reduce our energy costs.

We believe TMP with direct heat recovery to paper machine dryers has great potential and the installation at the Bathurst Division is due to start up in July of this year.

We look forward to further cooperation on your proposals in the future.

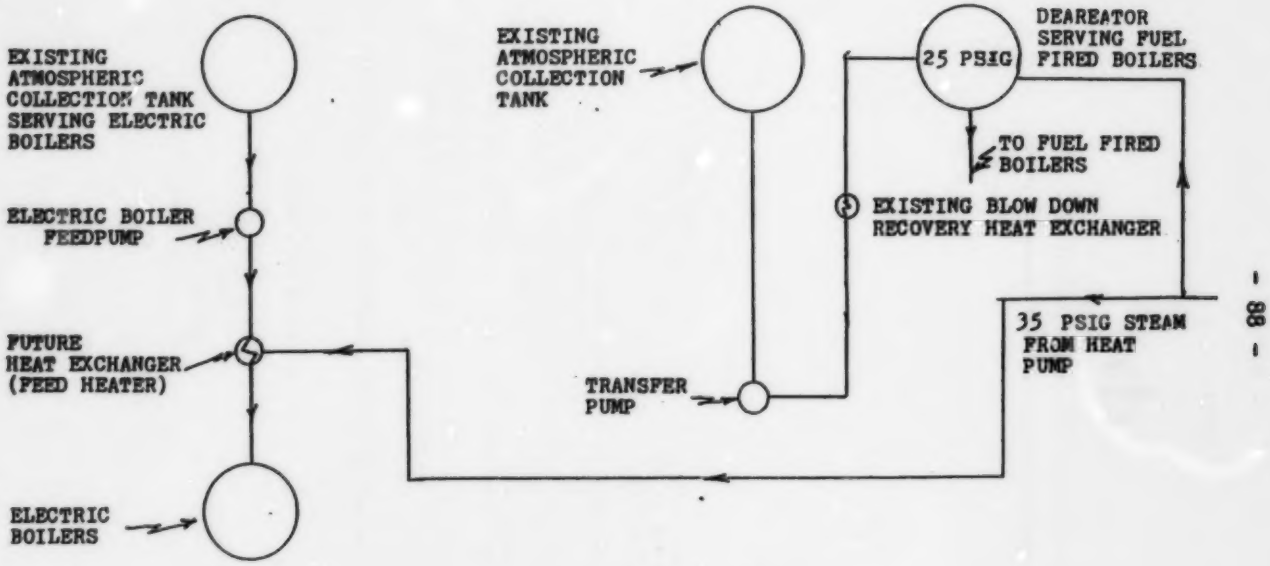
Yours very truly,

J. P. Woods

J. P. Woods,
Vice-President, Manufacturing.

JPW/F

FEEDWATER HEATING SCHEME FOR CONSOLIDATED BATHURST PORT ALFRED STEAM PLANT USING STEAM DIRECT FROM STEAM GENERATING FREON R114 HEAT PUMP

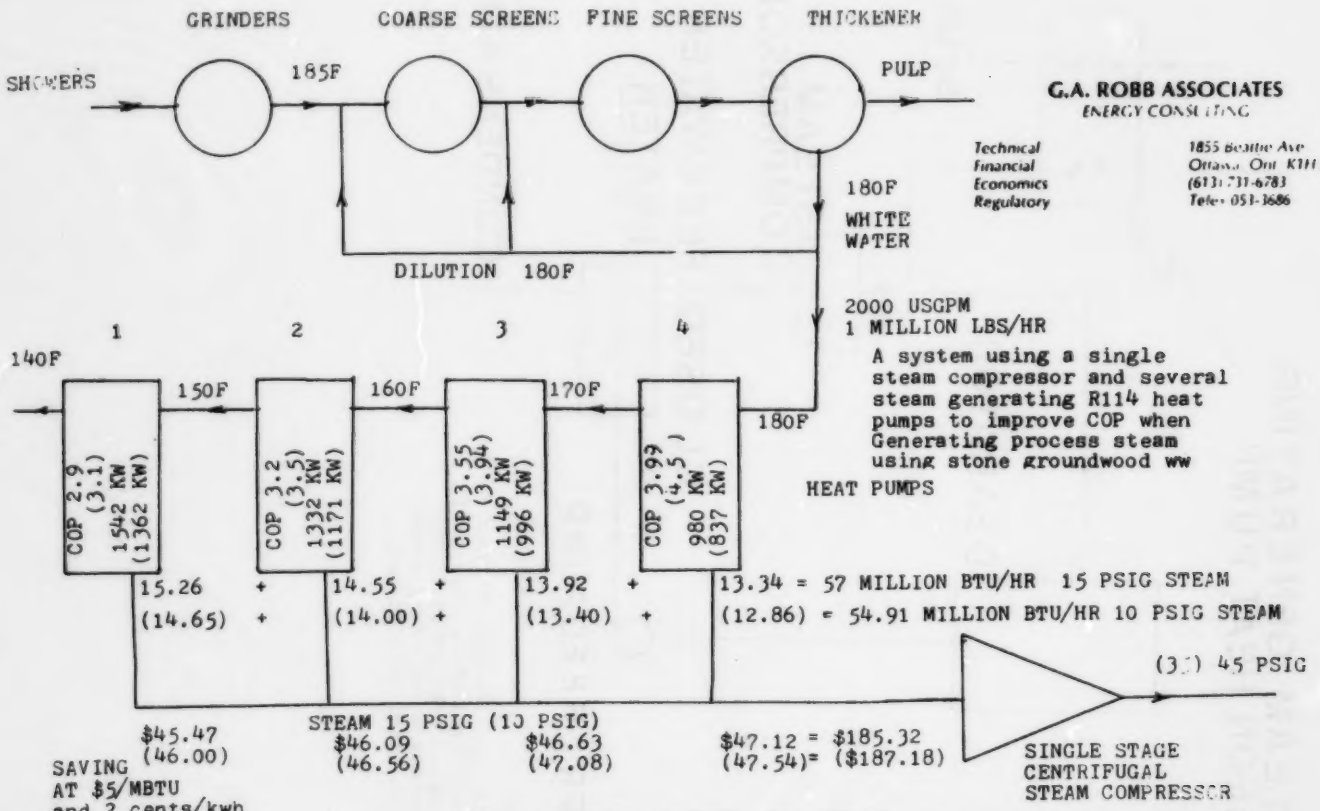

EXISTING ATMOSPHERIC COLLECTION TANK SERVING ELECTRIC BOILERS
ELECTRIC BOILER FEEDPUMP
FUTURE HEAT EXCHANGER (FEED HEATER)
ELECTRIC BOILERS
EXISTING ATMOSPHERIC COLLECTION TANK
TRANSFER PUMP
25 PSIG
DEAREATOR SERVING FUEL FIRED BOILERS
TO FUEL FIRED BOILERS
EXISTING BLOW DOWN RECOVERY HEAT EXCHANGER
35 PSIG STEAM FROM HEAT PUMP

G.A. ROBB ASSOCIATES
ENERGY CONSULTING

Technical
Financial
Economics
Regulatory

1855 Beattie Ave.
Ottawa, Ont. K1H 5R7
(613) 731-6783
Telex 053-3686

FIGURES PER TEN MILLION BTU REMOVED FROM SOURCE UNLESS OTHERWISE NOTED





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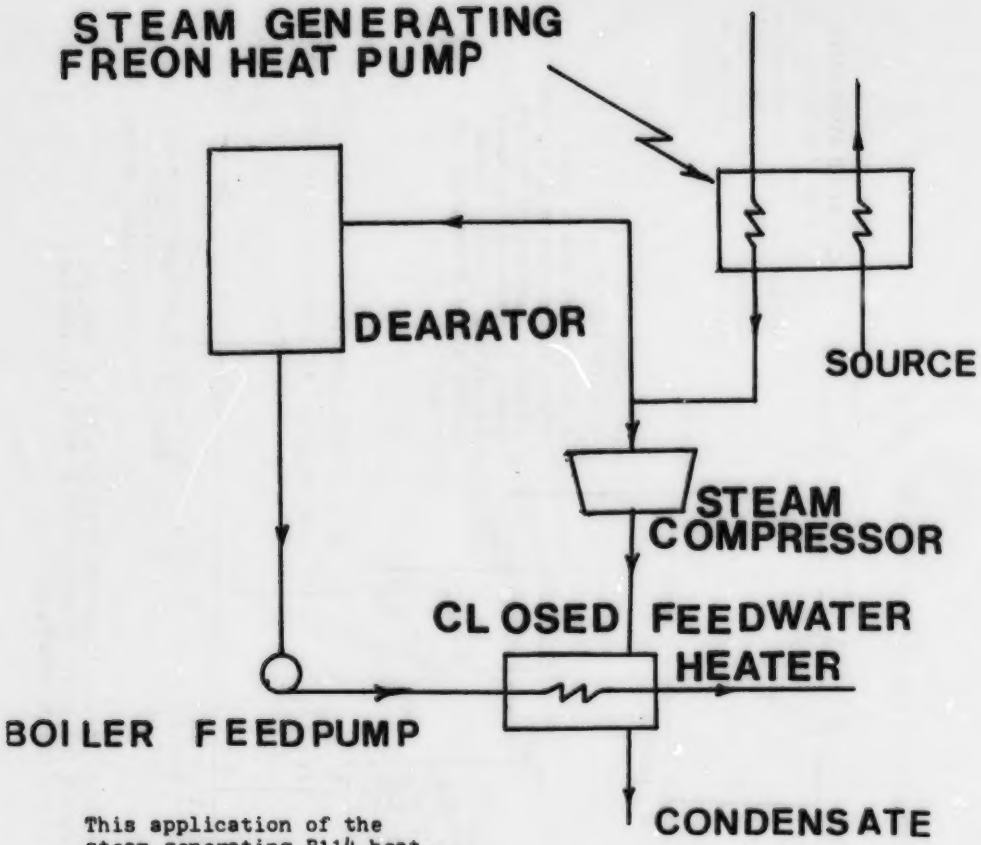
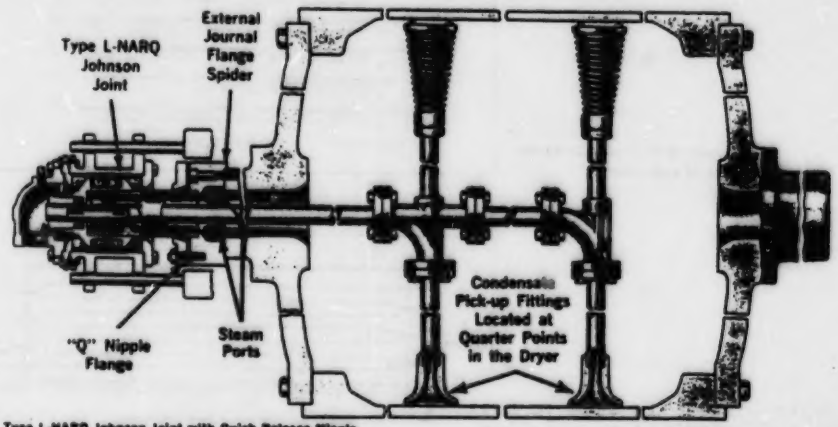
A system using a single steam compressor and several steam generating R114 heat pumps to improve COP when Generating process steam using stone groundwood ww

ANNUAL SAVING ASSUMING 8000 HRS/YR $1,482,560
EXCLUDING COST OF OPERATING SINGLE ($1,497,440)
STAGE STEAM COMPRESSOR



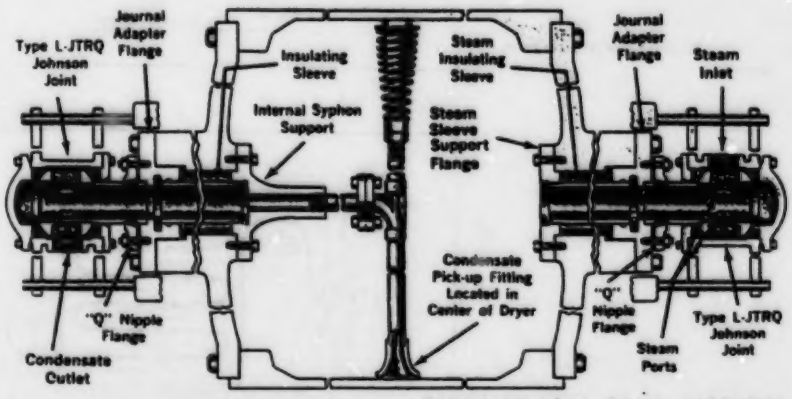

This application of the steam generating R114 heat pump is applicable to any process steam using plant with a suitable source


Type L-NARQ Johnson Joint
External Journal Flange Spider
"Q" Nipple Flange
Steam Ports
Condensate Pick-up Fittings Located at Quarter Points in the Dryer

- Type L-NARQ Johnson Joint with Quick Release Nipple
- Dual Johnson Rotary Syphons located at quarter points across face of dryer
- External Journal Flange Spider for Syphon Pipe Support

Note: Body lugs and support rods are turned 90° to show construction. Steam inlet is in side of joint body, not shown.

Figure 37



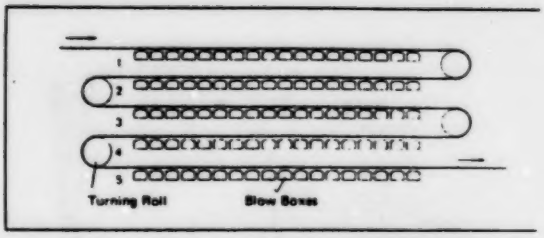

- Type L-JTRQ Johnson Joints with Quick Release Nipples
- Steam inlet one end of dryer, Condensate Outlet at other end
- Single Johnson Rotary Syphon ■ Steam Insulating Sleeves

Note: Body lugs and support rods are turned 90° to show construction. Steam inlet is in side of joint body, not shown.

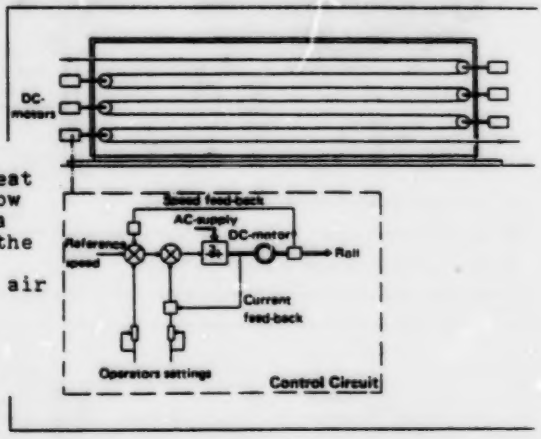
Paper machine dryer cylinder
Most of the steam used in a paper mill is used to evaporate water from the paper using these cylinders

13

Johnson Corp.

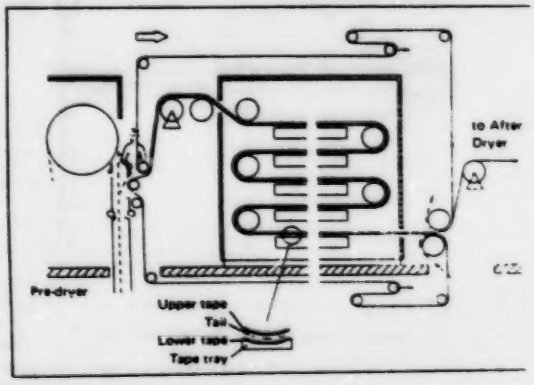



*A number of Drying Decks are stacked on top of each other*

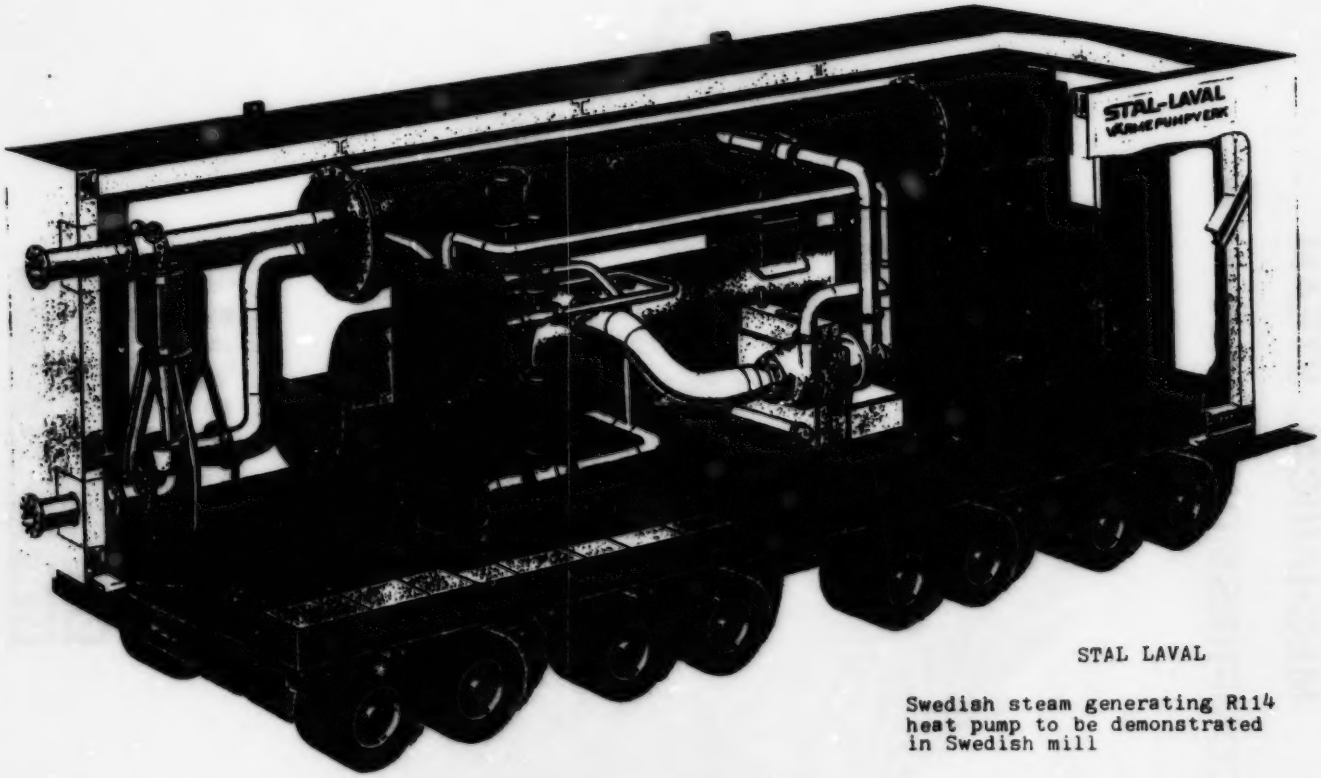



Pulp dryer - steam is used to heat air which is supplied to the blow boxes. The pulp is formed into a thick sheet and passed through the dryer where it is held in suspension and dried by the hot air

*DC-Drive System gives good control*




*Threading System — safe and simple*

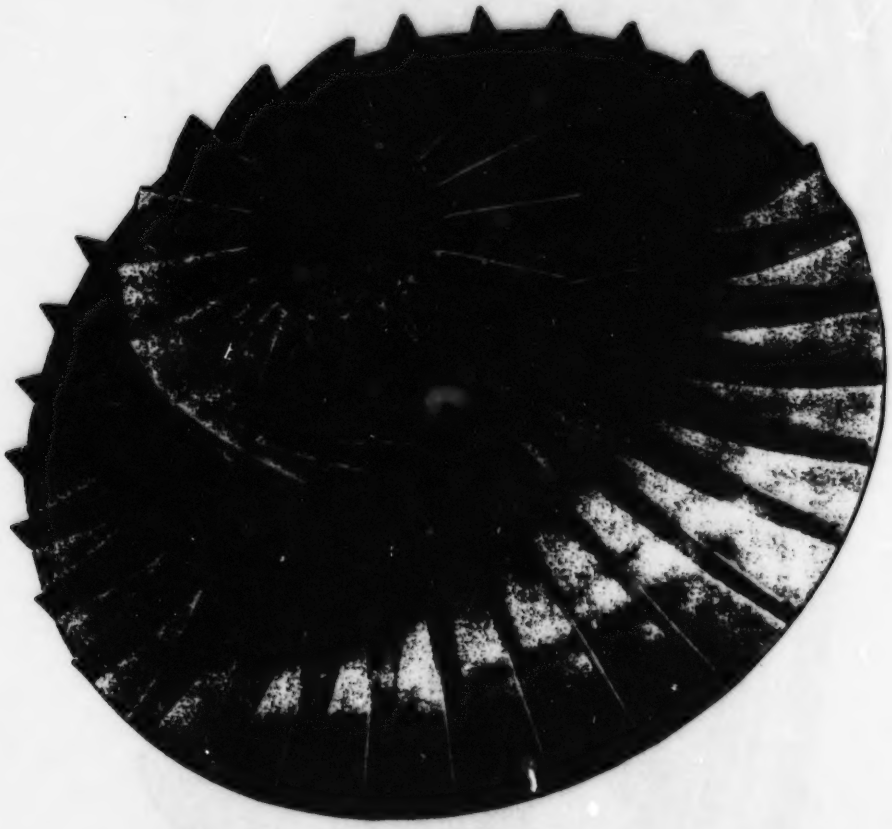



STAL LAVAL

Swedish steam generating R114 heat pump to be demonstrated in Swedish mill

5 MW VARMEPUMPVERK

# MECHANICAL STEAM COMPRESSION series "SM"

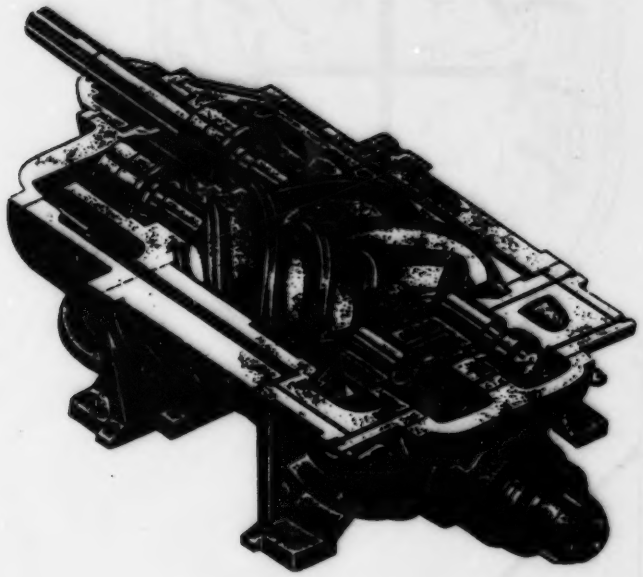


ALSTHOM ATLANTIQUE

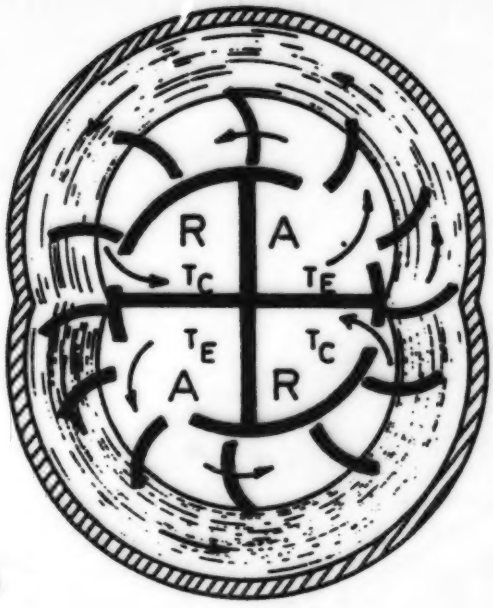
RATEAU

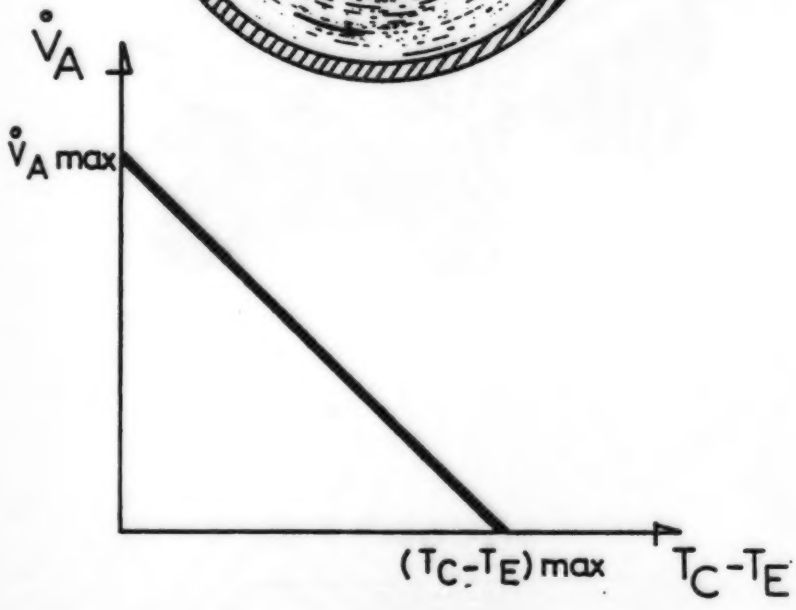
# HIGH TEMPERATURE HEAT-PUMP

Screw compressors are now used for steam compression as well as for refrigerants such as R114



MYCOM
CANADA LTD.
6651-E ELMBRIDGE WAY
RICHMOND, B.C. V7C 4N1
TELEPHONE: (604) 270-1544
TELEX 04-357629

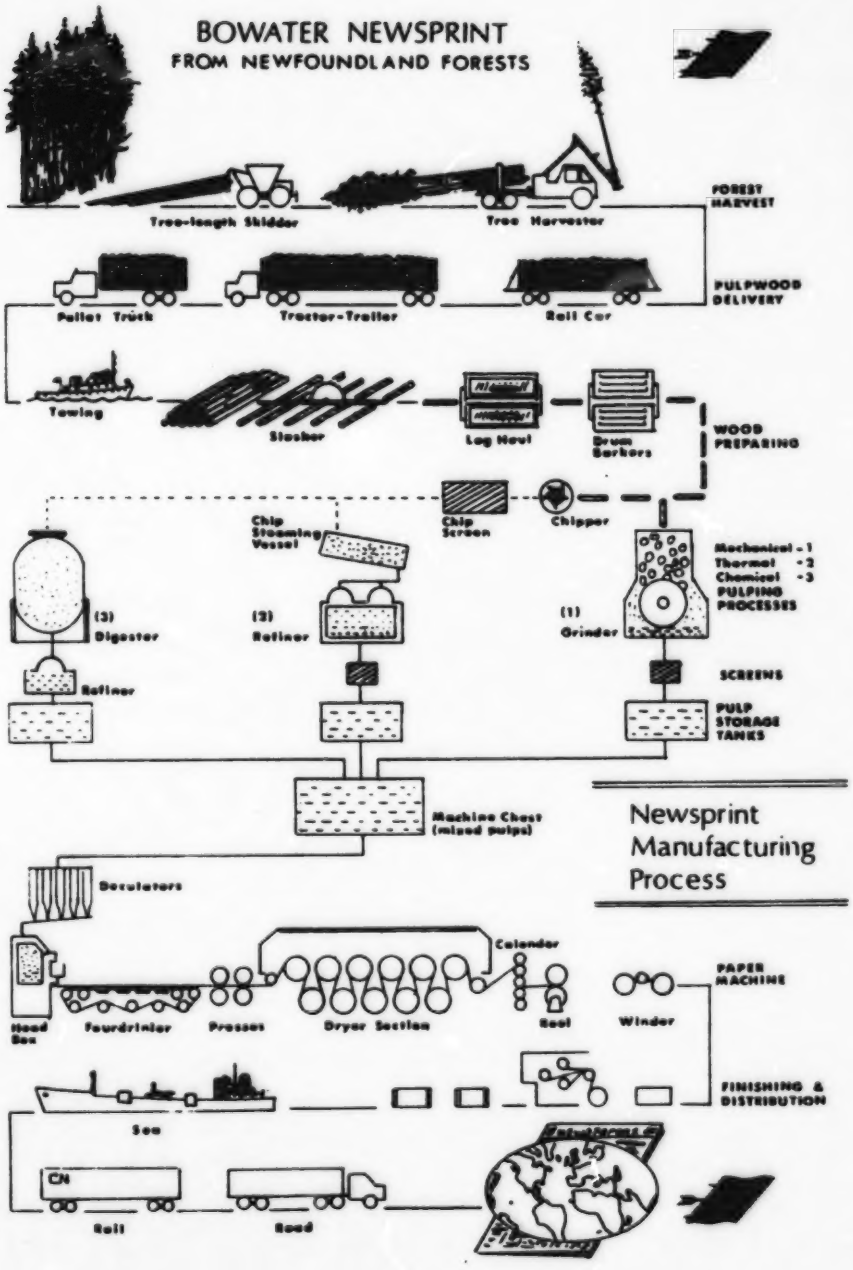



STEAM COMPRESSION USING WATER RING COMPRESSOR

SCHEME: 2

air industrie


BOWATER NEWSPRINT
FROM NEWFOUNDLAND FORESTS
Tree-length Skidder
Tree Harvester
FOREST HARVEST
Pallet Truck
Tractor-Trailer
Rail Car
PULPWOOD DELIVERY
Towing
Slasher
Log Haul
Drum Barkers
WOOD PREPARING
Chip Screen
Chipper
Chip Steaming Vessel
(3) Digester
(3) Refiner
(1) Grinder
Mechanical - 1
Thermal - 2
Chemical - 3
PULPING PROCESSES
Refiner
SCREENS
PULP STORAGE TANKS
Machine Chest (mixed pulps)
Newsprint Manufacturing Process
Deculators
Calender
Head Box
Fourdrinier
Presses
Dryer Section
Reel
Winder
PAPER MACHINE
Sea
CN
Rail
Road
FINISHING & DISTRIBUTION